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## A GREAT DYNAMO FOR THE PARIS CENTRAL LIGHTING STATION.

THE distribution of electrical energy over an extensive area, writes M. Hospitalier, in *La Nature*, involves either the indefinite multiplication of the number of stations or the employment of high tensions, if we would avoid expensive systems of canalization. The success of distribution by alternating currents and transformers depends on the facility with which these high tensions can be produced and transformed into low tensions in order to be utilized. Unfortunately, alternating currents involve serious dangers, and, from their very nature, are ill-adapted to applications of motive power, and cannot be employed at all for electro-chemical operations.

If to these objections we add the impossibility of storing up energy distributed under the form of alternating currents, we can easily understand why, in the greater number of cases, electricians should hesitate to use these currents, and why so many attempts are made to effect distributions by means of the continuous current, if not at a high tension, at least at an average tension, in order to retain both the advantages of high tensions from an economical point of view and the facilities of employment and storage offered by the continuous current.

Among the numerous systems of distribution having regard to these facts, either proposed or realized during the last few years, that adopted by the company of the section of the Place Clichy is worth describing somewhat in detail, for it shows once again the varied and, we may say, inexhaustible resources which the electrician has at his disposal for the solution of problems that are apparently most complicated. The problem solved in this case is the following:

Given a general system of canalization supplied by dynamos maintaining between the two conductors of the canalization a difference of potential of 440 volts, to divide this difference of potential into four equal parts of 110 volts each, on which it will be possible to establish utilizing apparatus that can be varied at will either in number or in power, without affecting the working of the other apparatus connected with the system.

It is, moreover, possible to connect apparatus working at differences of potential higher than 110 volts, and thus to obtain a distribution at several potentials, although the central station may only furnish one. This advantage will be highly appreciated when we have to establish motors of a mechanical power exceeding 10 kilowatts. These can then be installed on a difference of potential of 220 volts, electrical tramways with overhead or underground conductors being on the contrary supplied by the total difference of potential of 440 volts, economy always being kept in view throughout the system by employing, in each case, the highest potentials compatible with the good working of the receivers or other apparatus used. In order to understand the economy of this arrangement, we must examine in turn the central station, the canalization, the distribution and the regulating apparatus.

*Central Station.*—The central station established in the Rue des Dames, at Batignolles, in a splendid building erected for the purpose, comprises a series of tubular boilers, producing steam at a pressure of from 6 to 7 kilogrammes per square centimeter. This steam supplies three horizontal steam engines, of the Corliss type, each driving a large dynamo and three Armington & Sims engines of less power, each working two smaller dynamos. The only fact worth mentioning from a mechanical point of view is the intended and pre-arranged absence of condensation, notwithstanding the power to be produced, which exceeds 2,000 steam horse power when all the machines are working. The economy of fuel effected by means of condensation in an installation on this scale is of little importance as compared with the increased simplicity and safety of working gained by its suppression. Each of these steam engines of 600 H. P. turns at an angular speed of 65 revolutions per minute and works directly a continuous current multipolar dynamo producing 700 ampères and 450 to 500 volts, or 350 kilowatts. These are the most powerful continuous current dynamos at 500 volts that have yet been made. The armature is a Gramme ring 3·3 meters in diameter and 58 centimeters in thickness, with eight fixed inner poles. This ring is mounted on a projecting star of 30 rays. It consists of a number of sheets of iron supported on spindles of bronze, fixed on to the star, which is cast iron. Fig. 1 shows the construction of this colossal armature; Fig. 2 shows the winding of it, the coil consisting of 2,000 spirals formed of rectangular bars of copper. This armature has no collector, properly so called; the external portion of the bars with which it is wound serve to collect the current by means of eight series of brushes placed at 45° from each other. As the speed of the outer bars attains 12 meters per second, the brushes must rest very lightly in order to avoid wear and loss of work by friction. This result is obtained by mounting the brushes on flat brass springs, which gives them great flexibility. All the brushes, moreover, are mounted on one common frame, which enables them all to be brought in contact with the bars at once, and all to be at the same time brought into or displaced from the position corresponding to the suppression of the sparks, a position which varies according to the load on the machine.

The brushes can be displaced longitudinally along the rods which support them, so as to distribute the

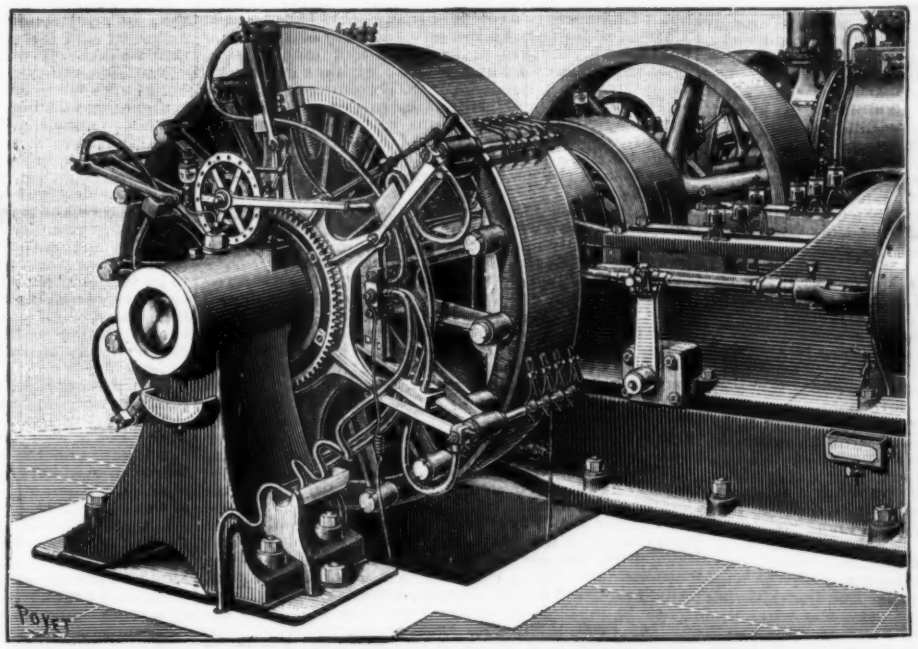

FIG. 3.—DYNAMO WITH RING AND INNER POLES; SIDE VIEW OF THE BRUSHES.

Type producing 160 kilowatts. The type of 350 kilowatts installed for the service of the Place Clichy differs only in its dimensions.

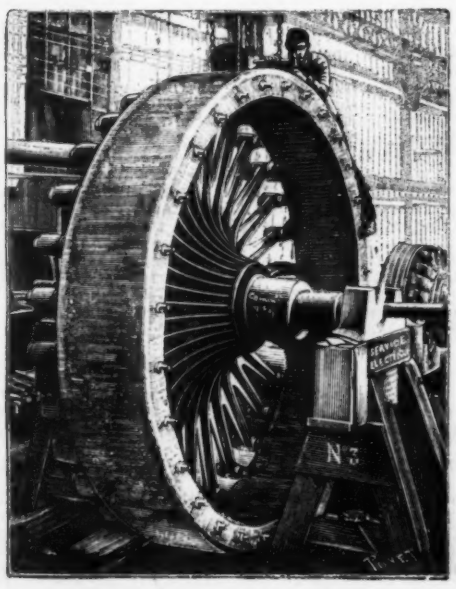

FIG. 1.—CONSTRUCTION OF THE GRAMME RING ARMATURE, 3.3 METERS IN DIAMETER.

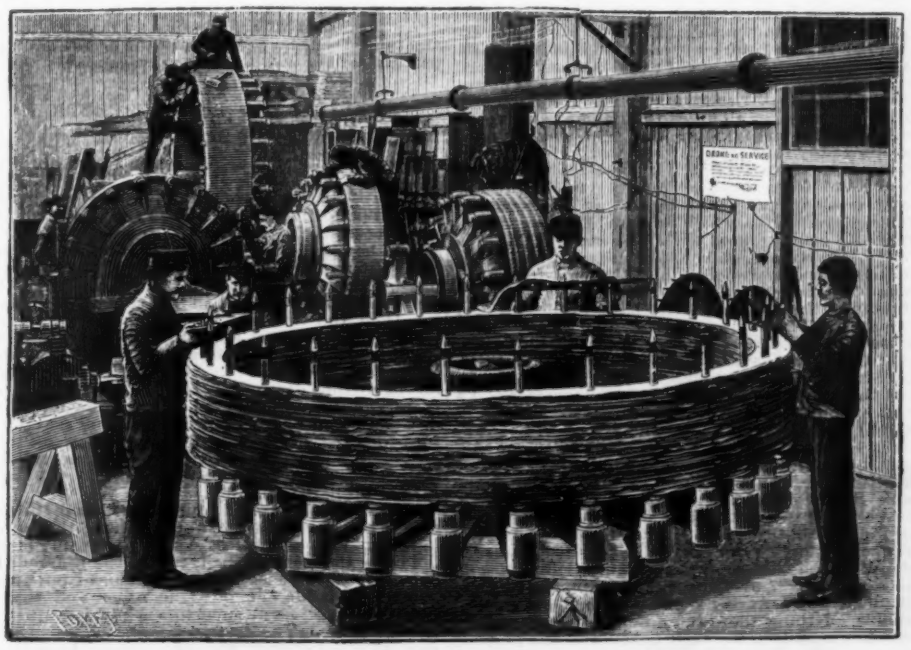

FIG. 2.—LARGE GRAMME RING BEING WOUND.

friction and equalize the wear, which is, however, very slight, of the collector. Fig. 3, which represents a dynamo of less power, but of the same type, shows clearly the arrangement of the armature collector and brushes, as just described. It is a type producing 160 kilowatts, used in less important stations; a model of this type was shown at the Universal Exhibition of 1889. The three large dynamos at the station of the section of the Place Clichy differ from this type only in

dimensions and power. The armature alone weighs eight tons, and special precautions had to be taken for its construction and transport from the works of the Alsatian Mechanical Constructions Company at Belfort, where it was made, to Paris. The three dynamos are connected directly, in the plan of the works, with two thick bars of copper, between which a difference of potential of from 450 to 500 volts is maintained. The excitation of each dynamo is equally established between these two bars, and may be regulated by means of a rheostat introduced into the circuit. Each rheostat may be manipulated independently in order to allow of the introduction or suppression of each machine in derivation on the bars, but all the rheostats can be connected together and manipulated at the same time for purposes of general regulation.

## THE INVENTIONS OF THOMAS DAVENPORT.*

By FRANKLIN L. POPE.

THE year 1837 marked a very important era in the history of the industrial development of electricity. During that year, two of the most extraordinary inventions of the present century made their advent in this city—the electric telegraph of Prof. Samuel F. B. Morse and the electric motor of Thomas Davenport. The motor came first. Davenport, a self-taught Vermont blacksmith, who had invented and constructed his machine in a remote country village in a crude form as early as 1834, came to New York in February, 1837, bringing with him some of the machinery which had been made for the purpose of exhibition, by himself and Ransom Cook, with a view to enlisting capital to build a large motor. During the season of 1837 he occupied rooms in the city where he exhibited models of his motor and various other electrical inventions. Articles were published in the newspapers of the day, and his exhibitions were attended by a great number of people. In letters written about that time, Davenport mentioned that one of the most frequent visitors was Professor Morse.

With the history of Professor Morse and his inventions of the telegraph the world is quite familiar. With the history of Davenport and of the invention of his electric motor—as I soon discovered in endeavoring to obtain information about it myself—scarcely anything was known. This difficulty ultimately led me to interest myself in trying to find out more about the matter. In this undertaking I was fortunately very much more successful than one can reasonably expect to be, in attempting to resuscitate the history of an invention which has lain unknown for the best half of a century.

The first newspaper notice of the electric telegraph which appeared in America was in the *New York Observer* in the summer of 1837. I will read you an extract from it:

"A gentleman of our acquaintance several years since suggested that any intelligence might be communicated almost instantaneously hundreds, if not thousands, of miles, by means of very fine wires, properly coated to protect them from moisture, and extending between places thus widely separated. It is well known that the electric fluid occupies no perceptible time in passing many miles on a wire, and if it is possible by connecting one end of the wire with an electrical or galvanic battery to produce *any sensible effect whatever* at the other, it is obvious that if there are twenty-four wires, each representing a letter of the alphabet, they may be connected with the battery successively in any order, and if so connected in the order of the letters of any word or sentence, that word or sentence could be read or written by a person standing at the other end of the wires. All the paragraphs of a newspaper could thus be touched by a man in Philadelphia, and the contents, *verbatim et literatim*, conveyed to New York as fast as a compositor could set up the type!"

It has always been a mystery to me what invention was referred to in that article. *The New York Observer* was edited at that time by a brother of Professor Morse. "The gentleman of our acquaintance" referred to was no doubt Professor Morse, but what was meant by the telegraph of twenty-four wires I could never make out, because we all know that Morse never entertained any idea other than that of a single circuit telegraph at any time from the beginning of his experiments in 1835, or earlier. But I received a few days since a letter from a gentleman who had read some articles recently published by me in reference to Davenport's work,† in which he stated that he visited Davenport's exhibition in the summer of 1837, here in the city of New York, and that he himself saw in that exhibition a model of a telegraph of twenty-four wires invented by Davenport, and that model must undoubtedly be the telegraph referred to in the extract I have just read.

In pursuing my investigations into the history of Davenport's work, I was fortunate enough to find that several of his original models were still in existence. One of these models, a circular railway two feet and a half in a diameter with a locomotive traveling on it, similar to the one which we have here to-night but very much more finely finished, I was able to satisfy myself by contemporaneous evidence was built in 1837. The one which is before you was found in the cabinet of the Female Seminary in Troy, formerly Miss Willard's. The records of the institution show that it was purchased in 1840, but it evidently must have been built by Davenport himself prior to the more finely finished model of which I have just spoken, which was constructed in 1836–37 with the assistance of Mr. Ransom Cook of Saratoga, an ingenious person and a finished mechanic. I thing there is no doubt that the model before us was built in the early part of 1837 and possibly as early as 1836. Fortunately it is, as you see, in a very good state of preservation. I have had it mounted to-night with the same battery that was found with it—a three cell Grove battery of pint cups—and I think we shall find that it is in tolerably fair running order. [The model was set in motion.] It does not go quite a hundred and twenty miles an hour, but it goes. This locomotive, you will observe, has a fixed field magnet below, and a revolving armature above, which is reversed twice in every revolution. So far as I am able to discover, that is a combination found in every practical motor to-day, which Davenport was the first to make known and to use in 1834. The motor is connected to the driving axle by bevel gear. The field and armature in the model before you are connected in series. In the other model of 1837 of which I spoke, they are connected *in shunt*. Among other models of Davenport was one having a horse shoe field and a four pole armature with curved pole pieces, which is really quite an advanced type of motor. That also was built in 1837. Altogether, Davenport, between 1834 and 1840, built over 100 motors of different patterns and of varying sizes, scarcely any two of them alike. I discovered also, quite to my surprise, that he was undoubtedly the first to make use of the solenoid with a movable core, as a means of moving machinery of any kind. He built in 1839 quite a large motor operating upon that principle, which from the best description I have been able to find of it, must have approached one horse power. He set that up at 42 Stanton Street, in New York; attached a printing press to it and started to publish the pioneer electrical journal of America—a small weekly paper called *The Electro-Magnet and Mechanics' Intelligencer*, printed by electrical power. Through the kindness of Mr. Davenport's son, Rev. Willard G. Davenport, I have the pleasure, on his behalf, of presenting to the American Institute of Electrical Engineers two copies of that paper. [Applause.]

These, so far as is known, are the only editions ever published; they are number one and number two. This was in 1840. I have received within a day or two an interesting letter from H. S. Davenport, a nephew of Thomas Davenport, still living in Vermont at an advanced age, who, as a boy, was with him a great deal and in that way became quite familiar with his work. I will take the liberty of reading extracts which give some idea of the manner of man Mr. Davenport was. He says:

"Many of his models never left his shop and were but little known even at the time of their construction. They were only made to show to how many uses the power could be applied, and also to work from on a larger scale, if he could get pecuniary aid to do so. The different models which interested me most at the several times I was in his shop were a trip hammer, a turning lathe and a machine for doubling, twisting and reeling cotton or silk, all at the same time. A circular frame fitted with two intersecting tracks, on which four miniature cork images glided around, he called his "puppet show." He was naturally of a retiring disposition, but when waked up was very strong in argument. His two favorite subjects were nature and electromagnetism. He considered magnetism the most important element in the creation of the universe, and thought it would be in its destruction. Magnetism kept the heavenly bodies in their places, and if that failed everything would be turned to chaos. He could see in every rock of the earth the battery of which it was composed. So also in the animal kingdom, the bones, muscles, and blood constituted a complete battery, which exercised a repulsive or attractive force wi h respect to another organism of the same kind. He was a great lover of fun and exceedingly fond of a joke. On one occasion he received an order from a party in Chicago for half a dozen bottles of electricity. He said he knew by the tenor of the letter that it was intended as a joke, and he accordingly replied that he bottled up his *wrath* for such would-be ignoramuses as he was, but had no electricity for him."

I might go on and relate many other facts of interest which I have learned about Mr. Davenport and his inventions, but the hour is already late, and I will forbear. But I may remark in conclusion that I find him to have been one of the most interesting characters with whom I have ever become acquainted, and I cannot but feel highly gratified that my attention chanced to be directed to the subject, in season to rescue at least some of the more important of his work from impending oblivion. In two or three years more it would have been too late. There are people now living, although at an advanced age, who knew him and remember him perfectly, but in a year or two more perchance they will be gone. [Applause.]

* Read before the American Institute of Electrical Engineers, February 24, 1891.

† See *The Electrical Engineer*, Jan. 7 *et seq.*

## LIGHTNING ROD PROTECTION.

By N. D. C. HODGES.

IN seeking a means of protection from lightning discharges, we have in view two objects—the one the prevention of damage to buildings, and the other the prevention of injury to life. In order to destroy a building in whole or in part, it is necessary that work should be done; that is, as physicists express it, energy is required. Just before the lightning discharge takes place, the energy capable of doing the damage which we seek to prevent exists in the column of air extending from the cloud to the earth in some form that makes it capable of appearing as what we call electricity. We will, therefore, call it electrical energy. What this electrical energy is, it is not necessary for us to consider in this place; but that it exists there can be no doubt, as it manifests itself in the destruction of buildings. The problem that we have to deal with, therefore, is the conversion of this energy into some other form, and the accomplishment of this in such a way as shall result in the least injury to property and life.

When lightning rods were first produced, the science of energetics was entirely undeveloped; that is to say, in the middle of the last century scientific men had not come to recognize the fact that the different forms of energy—heat, electricity, mechanical power, etc.—were convertible one into the other, and that each could produce just so much of each of the other forms and no more. The doctrine of the conservation and correlation of energy was first clearly worked out in the early part of this century. There were, however, some facts known in regard to electricity a hundred and forty years ago; and among these were the attracting power of points for an electric spark, and the conducting power of metals. Lightning rods were, therefore, introduced with the idea that the electricity existing in the lightning discharge could be conveyed around the building which it was proposed to protect, and that the building would thus be saved.

The question as to dissipation of the energy involved was entirely ignored, naturally; and from that time to this, in spite of the best endeavors of those interested, lightning rods constructed in accordance with Franklin's principle have not furnished satisfactory protection. The reason for this is apparent when it is considered that this electrical energy, existing in the atmosphere before the discharge, or, more exactly, in the column of dielectric from the cloud to the earth, above referred to, reaches its maximum value on the surface of the conductors that chance to be within the column of dielectric; so that the greatest display of energy will be on the surface of the very lightning rods that were meant to protect, and damage results, as so often proves to be the case.

It will be understood, of course, that this display of energy on the surface of the old lightning rods is aided by their being more or less insulated from the earth, but in any event the very existence of such a mass of metal as an old lightning rod can only tend to produce a disastrous dissipation of electrical energy upon its surface—"to draw the lightning," as it is so commonly put.

Having cleared our minds, therefore, of any idea of conducting electricity, and keeping clearly in view the fact that in providing protection against lightning we must furnish some means by which the electrical energy may be harmlessly dissipated, the question arises, "Can an improved form be given to the rod, so that it shall aid in this dissipation?"

As the electrical energy involved manifests itself on the surface of conductors, the improved rod should be metallic; but, instead of making a large rod, suppose that we make it comparatively small in size, so that the total amount of metal running from the top of the house to some point a little below the foundations shall not exceed one pound. Suppose, again, that we introduce numerous insulating joints in this rod. We shall then have a rod that experience shows will be readily destroyed—will be readily dissipated—when a discharge takes place; and it will be evident that, so far as the electrical energy is consumed in doing this, there will be the less to do other damage.

The only point that remains to be proved as to the utility of such a rod is to show that the dissipation of such a conductor does not tend to injure other bodies in its immediate vicinity. On this point I can only say that I have found no case where such a conductor (for instance, a small wire or gilding) has been dissipated, even if resting against a plastered wall, where there has been any material damage done to surrounding objects.

Of course, it is readily understood that such an explosion cannot take place in a confined space without the rupture of the walls (the wire cannot be boarded over); but in every case that I have found recorded this dissipation takes place just as gunpowder burns when spread out on a board. The objects against which the conductor rests may be stained, but they are not shattered.

I would, therefore, make clear this distinction between the action of electrical energy when dissipated on the surface of a large conductor and when dissipated on the surface of a comparatively small or easily dissipated conductor. When dissipated on the surface of a large conductor—a conductor so strong as to resist the explosive effect—damage results to objects around. When dissipated on the surface of a small conductor, the conductor goes, but the other objects around are saved.

Franklin, in a letter to Collinson read before the Royal Society, December 18, 1755, describing the partial destruction by lightning of a church tower at Newbury, Mass., wrote: "Near the bell was fixed an iron hammer to strike the hours, and from the tail of the hammer a wire went down through a small gimlet hole in the floor that the bell stood upon, and through a second floor in like manner, then horizontally under and near the plastered ceiling of that second floor, till it came near a plastered wall; then down by the side of that wall to a clock, which stood about twenty feet below the bell. The wire was not bigger than a common knitting needle. The spire was split all to pieces by the lightning, and the parts flung in all directions over the square in which the church stood, so that nothing remained above the bell. The lightning passed between the hammer and the clock in the above mentioned wire, without hurting either of the floors, or having any effect upon them (except making the gimlet holes, through which the wire passed, a little bigger), and without hurting the plastered wall, or any part of the building, so far as the aforesaid wire and the pendulum wire of the clock extended; which latter wire was about the thickness of a goose quill. From the end of the pendulum, down quite to the ground, the building was exceedingly rent and damaged. . . . No part of the aforementioned long, small wire, between the clock and the hammer, could be found, except about two inches that hung to the tail of the hammer, and about as much that was fastened to the clock, the rest being exploded, and its particles dissipated in smoke and air, as gunpowder is by common fire, and had only left a black, smutty track on the plastering, three or four inches broad, darkest in the middle, and fainter toward the edges, all along the ceiling, under which it passed, and down the wall."

### MATHEMATICAL THEORY.

There is stored up in each cubic centimeter of the column of dielectric from the cloud to the earth, just before the lightning discharge, an amount of electrical energy given by the expression $\frac{1}{8\pi} KE^2$, where K is the specific inductive capacity of the dielectric air, and E the electro-motive intensity, both in electrostatic units. This expression is given on p. 156, vol. i., second edition, of Maxwell's "Treatise on Electricity and Magnetism." Substituting the values of K and E (remembering, of course, that they are in electrostatic units), and reducing, we find that the amount of energy involved amounts very nearly to one foot-pound for each cubic foot of air involved. If we consider that the dissipation of this electrical energy takes place throughout the whole length of the column of dielectric from the cloud to the earth, we shall see that all the energy that we have to care for in our lightning rod is that existing in the section of the column contained between two horizontal planes passing through the top and foundation of our house respectively. This may not, of course, be strictly true, but it must be essentially.

No reason can be assigned why the electrical energy

should disappear at the top, or at the bottom, or at the center, of the column of dielectric in which it exists, so that it is reasonable to maintain that what we call a lightning flash is simply a line of air in which the electrical energy is being dissipated as heat. The energy, therefore, is transmitted, not from the cloud to the earth or from the earth to the cloud, but horizontally from all portions of the dielectric to some central core where it appears as heat, and where the phenomenon we call a lightning flash is manifested.

One result of this consideration is that, in order to produce the amount of energy which is known to exist in lightning discharges, the radius of the column of dielectric at the surface of the earth must be very considerable, in order that there shall be a sufficient mass of air to furnish, at the rate of one foot-pound per cubic foot, enough energy to produce the well known results.—*Science.*

## HIGH SPEED ELECTRIC RAILWAY WORK.*

By O. T. CROSBY.

THE experiments here reported were the first serious efforts ever made to at once double railway speeds, and as such should, I think, be systematically recorded.† They were made for the Electro-Automatic Railway Co., of Baltimore, Md. This company was organized about four years ago by David G. Weems, who, though not an engineer, was convinced that the electric motor would give very high speeds for the transportation of parcels. His persevering enthusiasm resulted in inspiring a number of gentlemen to subscribe money for the venture.

Mr. Weems first contemplated having an entirely automatic service from city to city, the cars to be smaller than would be necessary for placing a man. The experimental motor and track are shown in Fig. 1.

For purpose of demonstration, a circular track nearly two miles in circumference was laid at Laurel, Md.; gauge, 28 in.; weight of rail, 16 lb.; shape, T; cross ties, 3 × 4 in. square, 16 in. apart. Wooden stringers 3 × 4 in. were laid outside each rail, serving as guards. Mud sills 3 × 4 in. were laid under the ties, and to the ties was built up a vertical framework on both sides of track, this carrying from 2 × 6 in. cross pieces a wooden stringer, suspended above the middle of the track, while to the lower surface of the stringer was attached a small T rail, head down. This upper rail was intended to serve as an electric conductor, and also, in connection with upward pressing wheels, as a guide. The latter function was not successfully performed, the lateral oscillation of the car, on so slight a track, being too great. Part of the track was on trestle-

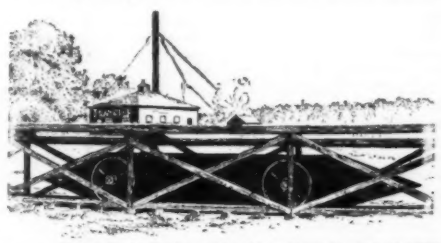

FIG. 1.—THE WEEMS HIGH SPEED ELECTRIC RAILWAY, AS OPERATED AT LAUREL, MD.

work crossing a swamp, the overflow of which caused frequent washouts.

The locomotive was very simple. Three axles carried 28 in. wheels; on these were hung a steel box, 16 ft. long × 24 in. high × 30 in. wide. A slight vertical play of the box was provided for by springs, but, horizontally, the three axles were in rigid connection. On each of these axles it was designed to place a motor. The head was pyramidal; the weight of the car with three motors was about three tons. A second similar box of steel was made to be drawn by the motor car, the two to be connected by a ball and socket arrangement, the interval between cars to be flanged over so that only one surface should be presented to meet atmospheric resistance. The tail was pyramidal. The second car was not in use more than once.

The track work and cars was completed as above outlined when the matter was brought to the Sprague Electric Railway and Motor Company, with the request that they design motors of which the armatures should be placed directly on the three driving axles of the car, the construction of which was already nearly finished.

It was further conditioned that the motors should do 20 horse power of work each at a normal speed of about 3,000 revolutions per minute. This corresponds to a car speed of about 250 miles per hour. Needless to say that on so light a track, none of which was straight, and with a car weighing three tons, and with only 60 horse power available for work, no such speed was attained. The motors were carefully designed by Mr. H. F. Parshall, of the Sprague Company, for a normal impressed E. M. F. of 500 volts, and thoroughly filled the specifications. They were to be connected in multiple across the 500 volt circuit supplied with current from a dynamo made by the Edison Machine Works. When the motors were finally mounted and ready for action, it was found almost impossible to start the car, due probably to stiff bearings, and when several trials of speed had been made, the results were disappointing.

Up to this time the electrical work had received only such engineering attention as could from time to time be given by employes of the Sprague Company, much occupied in other ways. It became evident to the Baltimore company that any satisfactory accomplishment could be had only through the continuous attention of some one having had electrical experience.

As superintendent of the Sprague Company, I had been familiar with the manufacture of the motors, and had moreover visited the plant; hence in October, 1889, it was arranged that further experiments should be under my direction. Throughout the work Mr. B. J. Dashiell, Jr., M.E., and Mr. H. F. Purdy, of the Sprague Electric Company, were of constant assistance, both in conception and execution of all that was done.

Work having been resumed, it was soon found that a given speed could be attained with less current if two motors were in service than with three, and consequently the motor on the middle axle was removed. It seems probable that, when running, this middle motor was largely occupied in skidding the wheels driven by it, since the two outer axles, on a yielding track, would doubtless support the greater part of the weight. In any case, the two motors were able to produce a greater speed than the track could stand. These machines were of the U type. The armature was wound with 100 sections of No. 12 B. W. G. wire, each section of two turns. This armature, with its commutator, was rigidly mounted on the axle. The pole pieces were attached to brackets centered on the axle, the keeper was spring-supported on a cross piece carried by the steel casing. Bearings were of phosphor bronze and lubrication by oil from an ordinary cup. No trouble on this score was experienced. Each magnet core was wound with 120 turns of No. 4 B. W. G. wire. At 30 amperes the armature induction was about 80,000 lines per square inch. Outline of the motor is shown in Fig. 2. These motors, since wound, according to specification, for the 500 volt circuit, were originally connected in multiple arc. This connection was changed, they being placed in series, thus diminishing the potential control required at the station by reason of the fact that the machines were run at a speed so much below that for which they had been calculated.

To supply the current, contact was made between the upper rail and brushes of sheet copper set against the rail by springs. These served their purpose well. The return circuit was through the wheels and rails, the steel casing being insulated from the axle by fiber plates and washers at joints and bolts. Rail bonds (covering joints in upper and lower rails) were used throughout; the resistance of the external circuit from the feeder junction to a point diametrically opposite was about 0·25 ohm. The station was placed inside the circle, about 200 ft. from the track. The generator was a 70 h. p. Edison machine, not compounded originally, and was driven by a 90 h. p. high-speed Ball engine. At first a wire resistance of about 12 ohms was used to lower the potential on the line, as it was not convenient to run the dynamos at less than 400 volts. Later, a whisky barrel was filled with water, an iron plate, 8 inches square, was placed in the bottom, a similar plate was fixed to the end of an iron rod and this rod attached to the pulley, permitting easy lifting or dropping of the plate through the water. These plates being connected in the main circuit, a very serviceable liquid rheostat resulted, which, when "taken with a grain of salt," answered excellently the purpose of regulating currents which often went as high as 150 amperes.

The usual course of a run was this: Speed-observers, as many as could be had, up to five or six, were stationed around the circle, distance apart being known. Watches of these observers and of recorders who read current and potential were compared. Potential readings were taken at station and at one or two points on the line, permitting easy reduction to horse power. Mr. Dashiell, my assistant, then took the engine and I managed the dynamo. A current of from 20 to 40 amperes usually started the car. The size of the armature wires limited to about 90 amperes—45 in each machine—the current permissible for any length of time. This value was usually attained in the first half mile of run, a considerable part of the external resistance having been cut out. When the car had attained a speed of 75 to 100 miles per hour, the line potential was in the neighborhood of 450 volts, the iron plates in the barrel being in contact, having been slowly approached as the counter E. M. F. increased. The time limitation of the runs was invariably caused by failure of the track to serve its purpose. On three occasions the car left the track; once at 45 miles per hour, once at 80 miles per hour, and once, the last time, at about 115 miles per hour. Curiously enough, on the two former occasions the derailment was to the inside of the circle, superelevation being about four inches.

It was easy to tell in the station when a derailment was imminent, as the ammeter was most violently agitated by the make and break of the circuit caused by the particularly bad spots in the track. The agitation increased with each trip around the circle and ended in a run-off, or, after some experience had been gained, in a cessation of the trial. As the track limited the length of run in time, so also it limited the speed obtainable. Each trial—the longest being about twenty-two minutes' consecutive running—was followed by an overhauling of the track, requiring from a few hours' to a week's work by four or five men.

Could the experiments have been made on a roadbed and track deemed even second-class according to steam railway standards of rail weight, etc., there can be no question that without any other change the car could have maintained for several hours a speed of 120 miles per hour. Indeed, I know of no time limitation that would have arisen save that from a limited oil supply.

The speed obtained in the first round—that is in the first 9,240 feet—varied from 30 to 75 miles per hour; this determined by the management of the rheostat. The *rate* of acceleration from point to point in going round the circle was irregular, due to the gra[illegible] very going in the direction usually followed, varied [illegible] to 2·5 per cent.

The fact that the track—always bad—went rapidly from bad to worse during each run, made it difficult to analyze the records with a view to determining the true coefficient of traction. Moreover, the coefficient for such a track, even in its best condition, would be greater than for the track that would necessarily be built for actual service. The figures obtained were of little worth as far as fixing absolute values at very high speed, but at least served to show the error of many train resistance formulæ found in the text books. Some of these formulæ give good enough results when used for the low speeds on which they are based, but their algebraic form is such as to give rise to great error when higher speeds, say 80 to 120 M. P. H., enter. This whole matter of train resistance has been more fully treated in a paper, "Limitations of Steam and Electricity," read by me before this Institute on May 21, 1890. The particular element of atmospheric resistance, for which special experiments were made at Laurel, was fully treated in a paper read by me before the West Point branch of the Military Service Institute, and published in London *Engineering*, issues of May 31 to June 13, 1890.

Using for atmospheric resistance figures resulting from the experiment herein referred to, we may analyze thus:

RUN OF OCTOBER, 1889—FLAT HEADED CAR.

Time of 1st round, 3·8 minutes. Average speed = 2430 F. P. M. = 28 M. P. H.
" 2d " 2·8 " " = 3300 F. P. M. = 37·4 M. P. H.
Average rate of work done by motors in 2d round = 15·0 H. P. 495,000 ft lb. per minute.
Average horizontal effort in 2d round = 495.000 ÷ 3,300 = 150 lb.
" " " " " for atmospheric resistance = 30 lb.
" " " " " for acceleration (approx.) = 10 lb.
" " " " " for other resistances = 110 lb.
" " " " " per ton = 110 ÷ 2·4 = 46 lb.

RUN OF NOVEMBER 13, 1889—FLAT HEAD.

Time of 1st round = 4·25 minutes. Average speed = 2170 F. P. M. = 24·7 M. P. H.
" 2d " = 2·5 " " = 3700 F. P. M. = 42·0 M. P. H.
" 3d " = 2·5 " " = 3700 F. P. M. = 42·0 M. P. H.
Average rate of work from middle of second to middle of 3d round = 15·5 H. P. = 511,500 ft. lb. per min.
Average horizontal effort = 511,500 ÷ 3700 = 138 lb.
" " " for atmospheric work = 36 lb.
" " " for acceleration = 0 lb.
" " " for other work = 102 lb.
" " " per ton = 102 ÷ 24 = 42·5 lb.

RUN OF NOVEMBER 13, 1889—PYRAMIDAL HEADED CAR.

Time of 1st round = 4·0 minutes. Average speed = 2410 F. P. M. = 26·2 M. P. H.
" 2d " = 2·0 " " = 4620 F. P. M. = 52·4 M. P. H.
" 3d " = 2·25 " " = 3678 F. P. M. = 41·8 M. P. H.
" 4th " = 2·25 " " = 3678 F. P. M. = 41·8 M. P. H.
" 5th " = 2·25 " " = 3678 F. P. M. = 41·8 M. P. H.
" 6th " = 2·25 " " = 3678 F. P. M. = 41·8 M. P. H.
Average rate of work in last four rounds = 16·0 H. P. = 528,000 ft. lb.
" horizontal effort = 528,000 ÷ 3678 = 144 lb.
" " " for atmospheric work = 24 lb.
" " " for acceleration = 0 lb.
" " " for other work = 120 lb.
" " " per ton = 120 ÷ 2·4 = 50 lb.

RUN OF DECEMBER 3, 1889—PYRAMIDAL HEADED CAR.

Time of 1st round = 4·3 minutes. Average speed = 2070 F. P. M. = 23·5 M. P. H.
" 2d " = 1·51 " " = 6120 F. P. M. = 70·0 M. P. H.
Average rate of work in 2d round = 41 H. P. = 1,353,000 ft. lb.
" horizontal effort = 1,353,000 ÷ 6,120 = 221 lb.
" " " for atmospheric work = 38 lb.
" " " for acceleration " = 42 lb. 80
" " " for other work 221 — 80 = 141 lb.
" " " for ton = 141 ÷ 2·4 = 58·7 lb.

The highest speed attained at this run was 90—95 M. P. H. Track was very bad, car derailed.

RUN OF DECEMBER, 1889—WEDGE HEADED CAR.

Speed maintained at 100 M. P. H. with rate of work = 44 H. P. Moreover, some work of acceleration was done, but records do not permit accurate determination of this. Omit acceleration, and we have:

Average speed = 8,800 F. P. M. = 100 M. P. H.
" horizontal effort = 44 × 33,000 ÷ 8,800 = 165 lb.
" " " for atmospheric work = 48 lb.
" " " for other work = 117 lb.
" " " per ton = 117 ÷ 2·4 = 48 lb.

* A paper read before the American Institute of Electrical Engineers, New York, February 24, 1891, President W. A. Anthony in the chair.

† Pressure of other work has prevented me from carefully reviewing the calculations appearing in this paper.—O. T. C.

Highest speed attained this run — 110 to 120 M. P. H. Track better than in last run, but car was derailed at maximum speed.

These values, 46·0, 42·5, 50·0, 58·7 and 48·0 lb., should be corrected for curvature, making them 30·7, 28·4, 33·4, 39·1, and 32 lb., respectively. Other and lower values were obtained when the track, as at first, was in better condition. But these earlier runs were not recorded in exact figures. The rails were in all cases rusty.

The speed at which this derailment took place could not be absolutely determined, since the car left the track at some distance from the last two observers, whose time records gave the speed attained between the points of observation. It was clear, however, that the final speed was between 110 and 120 miles per hour. A length of 1,000 ft. of track was injured, about 300 ft. of the upper framework wrecked, and the car itself was landed about 30 ft. from the track, having finally jumped the guard rails while going over a fill 4 or 5 ft. high. It seemed clear that the Laurel plant had passed its days of usefulness. Nothing further of value could be done without practical rebuilding. It was then time to make new plans, and this work was at once begun by Mr. Dashiell and myself. At the outset I felt that—if for no other than commercial reasons—we should plan for the carrying of passengers as well as parcels. This meant an increase in the size of cars and a change from an attempt at automatic control to control by human intelligence on the locomotive.

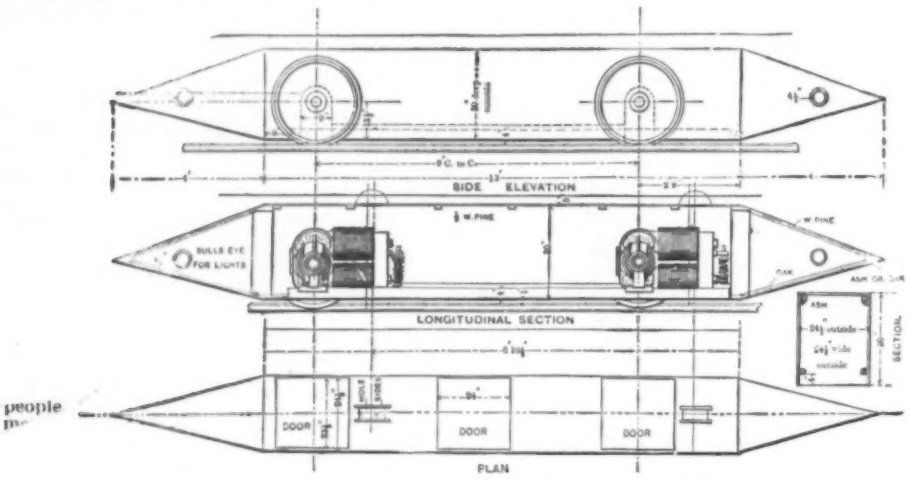


FIG. 2.—THE WEEMS ELECTRIC LOCOMOTIVE—ORIGINAL PLAN.

For purposes of demonstration I proposed to the company that they should build a track about four miles (not less) in circumference and should run thereon a train of two or three cars drawn by one locomotive. Calculations were based on the following data:

(1) A speed of 150 miles per hour on a level was to be aimed at.

(2) Cross section of car should be a minimum, consistent with the seating of passengers. This was taken at 6 ft. by 5 ft. 30 sq. ft. (crowning higher along middle of car).

(3) Gauge of track should be standard—4′ 8·5″.

(4) Character of track should be simply the best that art could contrive, rails to be from 65 to 90 lb.

(5) Electromotive force should be as high as the art of insulation would permit.

(6) Whatever might be the number of cars in a train, all were to be so connected as to present a continuous exterior, thus presenting only one cross section to the atmosphere.

(7) Atmospheric resistance at 150 miles per hour would be taken at 15 lb. per square foot of cross section, a wedge or parabolic locomotive head being used. This value is 50 per cent. in excess of that indicated by our experiments.

(8) Traction coefficient, exclusive of air resistance, would be taken at 150 miles per hour to be 25 lb. per ton—this for reasons set forth in previous papers.

From the two resistance coefficients just given, it followed that for every square foot of cross section, regardless of weight, 6 horse power would be required, and for every ton of weight, regardless of cross section, 10 horse power must be supplied.

For a locomotive of about 600 horse power having 30 ft. cross section, the dead weight was calculated to be about 18 tons. Steel cars of equal cross section were designed, weighing, empty about 5 tons, with carrying capacity of about 5 tons.

The important question as to power required could then be thus tabulated:

| | 150 M. P. H. | 130 M. P. H. |
|---|---|---|
| Locomotive alone | 360 H. P. | 288 H. P. |
| Locomotive and one car loaded | 460 " | 369 " |
| Locomotive and two cars loaded | 560 " | 446 " |
| Locomotive and three cars loaded | 660 " | 528 " |

To perform the work here indicated two motors were provided, one armature directly on each of the two axles of the locomotive car. These motors, outlined in Figs. 3, 4 and 5, were of the Manchester type. They were supposed to be at first connected in multiple arc across a 1,500 volt circuit, each taking about 139 to 150 amperes and delivering about 250 to 300 horse power. Should it be desired to experiment with higher line potential, the motors in series would permit 3,000 volts to be easily tried. The armatures of the Gramme type are 30 in. outside, 23 in. inside diameter. The armature conductors were to be of about 40,000 circular mils, cross section, or from 500 to 600 c. m. per ampere. Many successful machines, designed to work indoors, go as low as this figure, and since the dissipation of heat must in such case proceed more slowly than in the case here considered, the figure seemed very safe. Moreover, it was intended to introduce a blast of air from the car front which should continuously flow through the open center of the armature (Gramme type). How far the rate of dissipation would be carried by such means cannot now be known, but all recent evidence (see experiments of Mr. Kennelly) goes to show that the heat capacity would be much increased.

The cross section of core in the armature was 3·5″ × 40″—140 square inches gross, or, deducting 15 per cent. for paper insulation between disks and 8 per cent. for conductor slots cut in periphery, 110 square inches net. Through this armature it was desired to force 22,000,000 lines (C. G. S. units) or 100,000 per square inch — 15,000 per square centimeter.

The hysteresis loss in such armature revolving at 1,200 R. P. M. (equivalent with 42 inch wheel to 150 M. P. H.) was calculated to be about 3,000 watts—following the curve published by Esson. The $C^2 R$ loss ($C = 135$ amperes, $R = 0{\cdot}26$ ohm when $T = 75°$ C) = 4,740 watts—or about 8,000 watts for the two losses. I found it difficult to obtain such coefficient as would give reliable values for loss due to Foucault currents. With very thin plates it would not be large. From what precedes, it followed that the number of armature conductors should be 340. These were divided into 170 sections, wound in one layer, each conductor to lie in a slot; both slot and conductor were planned to be rectangular, or nearly so, with the reservation that experience in manufacturing would soon show the proper detail.

The magnets have a cross section of 164 square inches, through which 14,300,000 lines of force must pass, the increase from the number in the armature being determined by a leakage coefficient 1·3.

The magnet coils of the two armatures were calculated to be in series with each other, but in shunt with respect to the two armatures. This variation from present street car practice I thought to be justified by the following considerations: First, no system of commutation could obviate the need of a considerable external resistance, which then could be easily made sufficient, within itself, for speed control; second, the maximum torque for a given armature current is always desirable and can be best obtained by permanent saturation; third, this constant and maximum magnetization would tend to diminish sparking—an evil to be specially avoided in long distance work, involving continuous runs of several hours.

While it was thus intended to use shunt coils at first, I felt that a little experience would soon positively demonstrate that the advantage lay with this or the series winding.

The commutator, Fig. 3, was designed to be 23 inches in diameter, which would of course give rise to a very high speed relative to the brushes. I believe it better to face the mechanical trouble that might be connected with great circumferential speed rather than to diminish the diameter by decrease of sections, since this in turn might produce sparking.

Without going into the mechanical details of the commutator, I may add that a single bar could be taken out or replaced, without removal from the shaft.

The rheostat for the armature circuit was designed to be of iron wire, with the expectation, however, of experimenting also with liquid or carbon resistance. The resistance and heat capacity of this main line rheostat were determined with reference, first, to current necessary for starting, second, to currents needed for maintaining low speeds. The starting current on practically level track was calculated to be from 300 to 400 amperes, the load being 80,000 pounds (or locomotive and three loaded cars). For continuous running at 30 miles per hour, a current of 40 amperes would be required, the counter E. M. F. of each of the 1,500 volt motors being, at this speed, only 320 volts. The line potential being 3,000 volts, it would be necessary to have in the armature circuit an external resistance of

$$59{\cdot}0 \text{ ohms} = \frac{3000-640}{40}$$

The wires were calculated to stand 40 amperes continuously, and the various sections were proportioned to stand the various currents for such time as would serve to bring the train up to speed. It was, of course, known that a considerable reduction in the size of resistance box could be effected by winding the motors for the regular line potential, thus normally working them in arc, but putting the armatures in series where a great reduction in speed might be required.

A small rheostat and a condenser were designed to be placed in the circuit of the magnet coils, and a rheostat also in the lamp circuit, these resistances giving delicate control.

The problem of retardation for a mass of say 40 tons running at 150 miles per hour is a serious one. The Galton and Westinghouse tests indicate a very low value for the coefficient of friction between brake-shoe and wheel, at high speeds; they report in some cases at 60 M. P. H. as low as 0·04. As, however, it rapidly increases at lower speeds, an average of 0·1 may be taken. The total retarding effort, *i. e.*, brake resistance and track and atmospheric resistance, must be kept below that which will just produce sliding of the wheels, and the coefficient of sliding may be taken on an average at 0·8 of the weight of the wheels. If then we represent by P the maximum allowable brake pressure on the wheels, by R resistances other than brake friction, and by W the weight on braked wheels, we may write the following inequality: $0{\cdot}1\,P + R < 0{\cdot}08\,W$.

The value of P should be determined as that which, with a small margin, will satisfy this condition of inequality.

Following this calculation, it was found that a brake pressure of about 5,000 pounds should be applied to each wheel. This was designed to be produced by magnetic brakes similar to those used by Mr. Daft on the New York Elevated Railway. The form and approximate dimension of those brakes are shown in Fig. 4.

A mass of 80,000 pounds moving at 150 miles per hour represents 64,000,000 foot pounds of energy. Average resistance due to brakes = 0·1 × 60,000 = 6,000 pounds. Average resistance from track and atmosphere for average speed of 75 miles = 400 pounds.

In addition, the motors may be required to generate a current which shall be wasted over the rheostat. Since the field circuit, in the case of shunt motors, is independent, magnetization may remain constant, and average E. M. F. of 1,500 volt motors (*i. e.*, motors generating 1,500 volts E. M. F. at 1,100 R. P. M. or, with 42″ wheels, at 150 E. M. F.) would be, while the train was coming to rest, 750 volts. Make the external resistance such that, the two armatures being in series, an average current of 200 amperes shall flow. The average dynamo resistance in pounds = 2,000. Total retarding effort = 6,000 + 400 + 2,000 = 8,400 pounds. Dividing 64,000,000 by this last quantity, we have 7,620 feet as the length of run to come to a stop, and the time of stopping about 100 seconds.

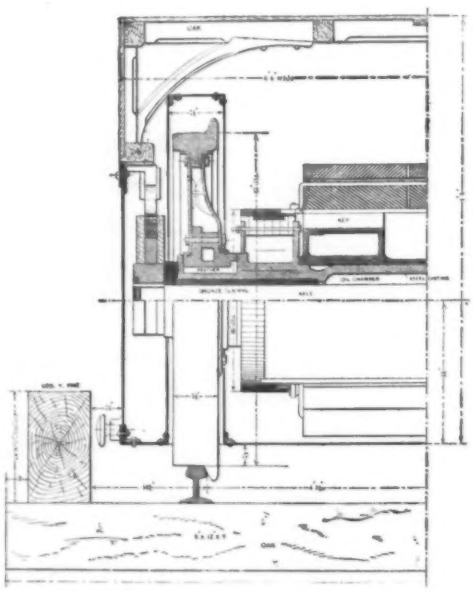

FIG. 3.—HIGH SPEED ELECTRIC LOCOMOTIVE. HALF CROSS SECTION.

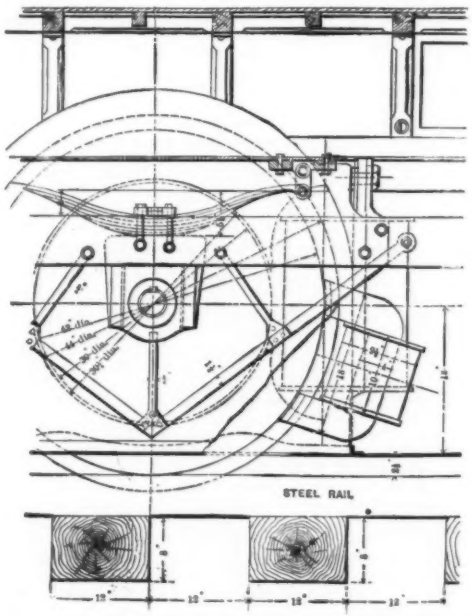


FIG. 4.—HIGH SPEED ELECTRIC LOCOMOTIVE. BRAKE MECHANISM.

For the mechanical construction of the locomotive, two plans were contemplated. One has a 12-foot rigid wheel base and no pilot wheels; the other has a 7-foot wheel base for the drivers and a pony axle in front, free to move laterally over a certain distance, dragging the drivers in the same direction. This is the general principle of pilot wheels, so largely used on high speed engines. This second arrangement, Fig. 5, is preferred.

In it nearly all the weight goes on the drivers. In this particular case, total weight of locomotive is about 18 tons, each motor being six tons. Of the total 15 tons rest on the drivers. If then the adhesion coefficient, while running, be taken at only 0·1, a circumferential effort of 3,000 pounds may be exerted without slipping the wheels. This is safe, since if 600 h. p. of work be required at 150 miles per hour ( = 13,200 f. p. m.), the

$$\text{horizontal effort} = \frac{600 \times 33{,}000}{13{,}200} = 1{,}500 \text{ pounds.}$$

For starting the load, adhesion coefficient may be taken at 25, giving 7,500 pounds possible pull, this being much in excess of the value required.

The locomotive construction is such as to put the entire weight of the armature directly on the axle. In designing this, I did not overlook the fact that the armature must thus be subjected to much jarring. But I believe the difficulty should be met by excellent mechanical construction, rather than that spring movement should in any way be attempted. For mechanism that shall succeed in high speed, long time service, simplicity is a requirement of the first order. Indeed, generally, in this work of connecting an electrical motor to any vehicle, I have long felt that he who is over-ingenious in contriving many parts and fine adjustments may not be over-successful.

The weight of the magnets and pole-pieces goes also directly on the axles, save for the intervention of rubber plates having a maximum play of 1-16 of an inch. By the use of motors of the "U" type, part of the weight might be spring-supported, but on the other hand it is not as easy, with that type as with the Manchester, to obtain a perfectly sparkless motor. Moreover, the weight going dead on the axles in the case

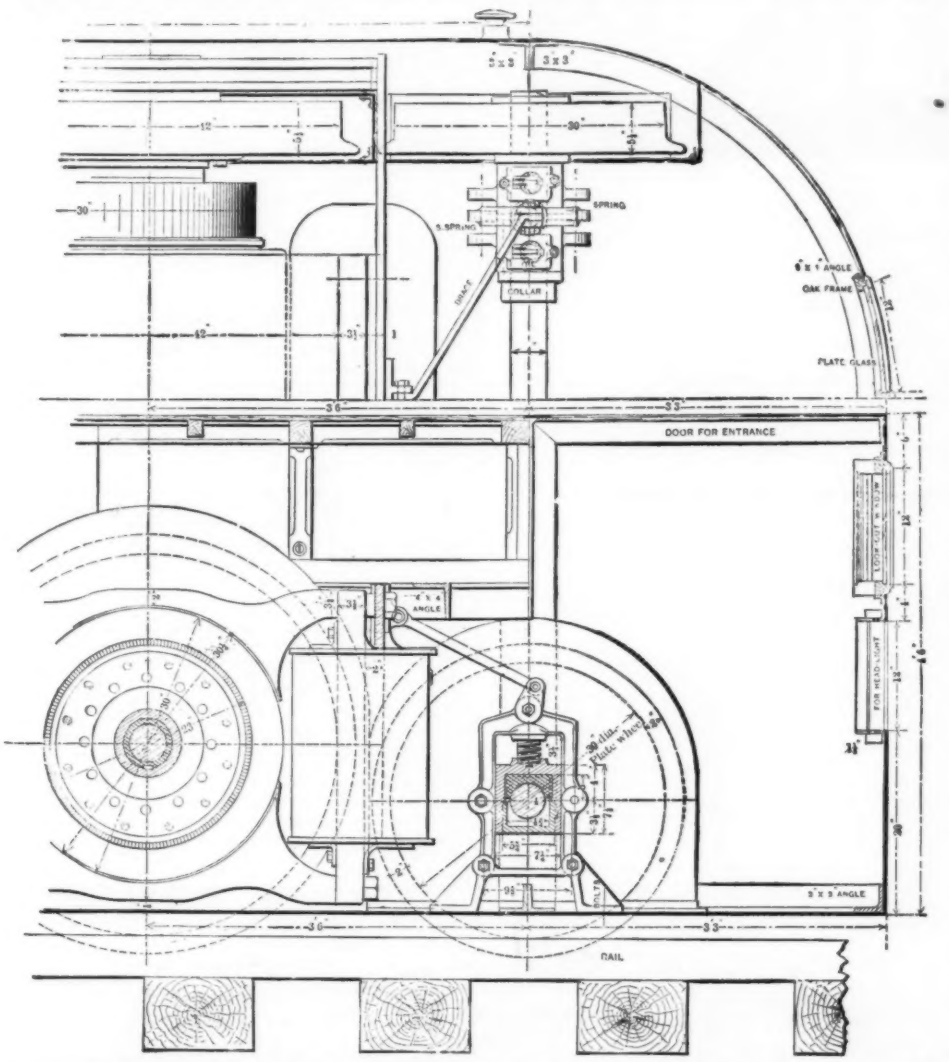


FIG. 5.—HIGH SPEED ELECTRIC LOCOMOTIVE—END OF CAR, ELEVATION, AND PLAN.

considered is not greatly in excess of that due to 8-foot drivers and other attachments of large steam locomotives. Further the need of any spring movement decreases with increasing perfection of track work, as in an ideally perfect track car springs would not, save on curves, come into play.

In the first design of locomotive cars, the operator is to sit between the two motors, where also would be placed the controlling devices. In the second design, the operator would be placed over the pony axle, the devices being chiefly in the cylindrical or parabolic head.

Detailed drawings of freight and passenger cars were completed, but need not here be referred to.

As to the supply of current, it is proposed to use the double metallic system. This departure from the ground return, now so commonly employed in street railway work, seems justified by the following considerations:

1st. For a given voltage it diminishes the cost of insulation, *per se*.

2d. It diminishes the danger of accident within the motors.

3d. It diminishes danger of accident to workmen.

4th. By being thus more easily handled, it is probable that a higher voltage will be found practicable than with the ground return; hence, in fact, even first cost might not be greater.

As designed, the conductors will be placed in an inverted wooden trough, attached to posts placed at 12 feet intervals on each side of the track. The trough to be about 5·5 feet above the ground. The conductors for each side of the circuit to be two—one insulated and continuous; the other a bare, flat strip, broken into sections, these being normally out of circuit; the locomotive trolley arm operating a switch which shall throw out the rear section, and throw into circuit the section ahead. Such a switch was designed in detail.

As to what the line voltage should be, progress in the art of insulation can alone determine. It would, of course, not be necessary, on a roadway for long-distance travel, to consider the death-producing voltage as a limitation.

In the important matter of limiting curvatures, calculations were made in the ordinary way, using the particular values for weight and height of center of gravity. A safe speed was then tabulated as that which is just one-half the speed that causes the resultant of weight and centrifugal force to pass through the outer rail of a curve. The beneficial effect of superelevation, neglected in the calculation, would, of course, practically increase the factor of safety.

The following table resulted from the method described:

| Radius in feet. | Safe speed by rule above in miles per hour. |
|---|---|
| 1,000 | 71 |
| 2,000 | 98 |
| 3,000 | 120 |
| 4,000 | 140 |
| 5,000 | 158 |
| 6,000 | 172 |
| 7,000 | 187 |
| 8,000 | 198 |

Of course, naught save practical trial could determine whether the assumed factor of safety, which is quite large enough at present speeds, would, in fact, be right for the higher speeds aimed at.

### COMMERCIAL ASPECTS.

Copper calculations were made, based on a station potential of 3,000, and also of 6,000 volts, stations being 50 miles apart (thus supplying current 25 miles on each side) and on a service requiring one train on each 25 mile section, the drop on the line being 33 per cent. of station potential. Then for a line of 1,000 miles, as from New York to Chicago, with copper at 15 cents per lb., and for 3,000 volts initial:

| | Per mile. |
|---|---|
| Cost of conducting system, including framework | $7,000.00 |
| Cost of station per mile, including steam | 3,000.00 |
| Cost of double track, including depots, etc. | 55,000.00 |
| Cost of train equipment, 3 cars each, 50 trains and engines | 1,000.00 |
| Total per mile | $66,000.00 |

In this the cost of track construction is based on roadbed figures reported for the Erie Railway Co. To arrive at operating expenses, suppose 20 trains each way each day, and a schedule of 125 miles per hour, *i. e.*, 8 hours for the trip. Suppose a station development of 800 horse power per train on the line, or 64,000 horse power hours per trip. In stations of large capacity working under the supposed conditions, the cost of one horse power hour = 0·90 cent (see tables in previous paper, "Limitations of Steam and Electricity") or per trip for power a cost of $57.60. For train men, suppose two men on each train, and 1 per train in reserve, and suppose $3 00 per man per trip of 8 hours, then cost per train trip = 3 × 3 = $9.00. Interest charged per train trip =

$$\$66{,}000{,}000 \times 0.05 \div 365 \times 40 = \$225.42.$$

For maintenance of way (see Wellington's Statistics), take $1,000 per mile of double track per annum, or per day for supposed line, $2,700.00; or per train trip, 2,700 ÷ 40 = $67.50. For general expense of operating company, suppose $1,000.00 per day—or per train trip $25.00. For wear and tear, oil, etc., on train itself, take $10.00 per trip. Then total = 56.60 + 9.00 + 225.42 + 67.50 + 25.00 + 10.00 = $394.42. For receipts:

Suppose average train be of two cars (such as designed), having each a capacity of about 10,000 lb. freight (considered such, as express and mail matter), or of say fifteen passengers. Suppose average train load of freight, 15,000 lb., of passengers, 20. Take freight at 33 cents per cwt., passengers at $25.00. The income per trip in either case—$500.00; showing profits, over fixed charges of say $100.00 per trip, or $4,000.00 per day. The total daily load of freight, each way, required to justify the service above treated, is 300,000 lb., or if 200 through passengers be carried (*i. e.*, ten trains for passengers each way each day), then only 150,000 lb. of freight. The *present* movement between New York and Chicago, in mail and express, is not far from this figure. A five hundred mile line, connecting Boston, New York, Philadelphia, Baltimore and Washington, would be even more profitable. It is to be remembered also that a service of *small* trains is contemplated, making fixed charges relatively very large. Much larger trains could be, and I think *will be*, run at the speeds here considered, but I have supposed that the smaller effort would precede the larger. It is further to be noted that the use of 6,000 volts potential, and the extension of some existing roadway instead of the building of a new one, would diminish first cost. As grade crossings would be out of the question, and as cities would require to be entered above or below the surface (country roads to be carried over on bridges), it is perhaps best to consider only the larger figure already used.

To demonstrate all or nearly all that has been outlined in this paper will cost about $300,000, covering the construction and operation for a reasonable time of the four mile circular line proposed above. Last year the Baltimore company met unexpected difficulty in efforts to raise the needed money; their operations were suspended and my connection with them ceased just at the time when the plans were completed—even to working drawings. I have been much pleased to learn, within the last few days, that far from being discouraged, they are now confidently hoping that they may push on in the near future the great work to which they have laid their hands.

Unfamiliar as is the project, you will perhaps be the more ready to share the confidence of its promoters, on hearing the words from Prof. Henry A. Rowland and Dr. Louis Duncan, of Johns Hopkins, to whom were submitted, last spring, full details of the plans partially described in this paper, after reviewing the figures for power required. They say:

"We believe from the data obtained that the values given are not too low, and that the horse power which Mr. Crosby calculates is *not less than the amount required.* While we have investigated carefully and considered all the data obtainable, yet the existing experiments are not sufficient to accurately fix a limit to the train resistance. *We believe, however, that the value assumed by Mr. Crosby is safe.*"

"The motors, the calculations and drawings for which are in the appended statement, will develop the horse power for which they are designed, namely, 500 horse power. We point out some modifications which will be beneficial. *We believe that they will drive the train* (locomotive and two cars, O. T. C.) *at the required speed.*" (Italics here and elsewhere are mine; speed then considered, 120 miles on a level. O. T. C.)

"The possibility of a train being derailed by an obstruction on the track increases with the speed. At speeds up to 90 miles, however, there seems no increase in the number of derailments. In the case in question, the center of gravity of the cars is very low, and *it would be difficult to derail them on straight parts of the track.*

"The radius of the curves should of course be great, but not so great as would be required for an ordinary train going at these high speeds. *The question of safety is,* however, *almost wholly a question of track construction.* Considering the form of the proposed train, its comparatively light weight, making a less demand on the track, it is certain that, with a carefully constructed road, it could attain with safety speeds which would be impossible with trains as at present constructed. As these latter have several times made 86 miles, and often made 80 miles, *it would seem that a speed of 120 miles or even more, with the electric cars, would not be outside the limits of safety.*"

"The plan for supplying current to the motors is feasible."

"The design of the motors is discussed in the detailed report. It is generally good."

"Should it be demonstrated by an actual test that passenger trains can be run safely and economically at a speed over 100 miles per hour from here to Chicago, the financial aspects of the case would certainly be improved. *We are of the opinion that the chances are in favor of this being accomplished by the present scheme.*"

These words, though guarded and accompanied by criticism of the detail, are yet a substantial approval of what was submitted. To me they were very encouraging.

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FOUR storage battery electric cars on the Lehigh Avenue Railroad, Philadelphia, have been withdrawn after successful use for a considerable period. The business of the road was insufficient to support the electric plant, which costs nearly as much for a small number of cars as for a large number.

## TRAIN SHED OF THE GRAND CENTRAL PASSENGER STATION, CHICAGO.

ON the evening when the station was formally opened to the public a great display of incandescent lamps was made in the train shed, and the brilliant

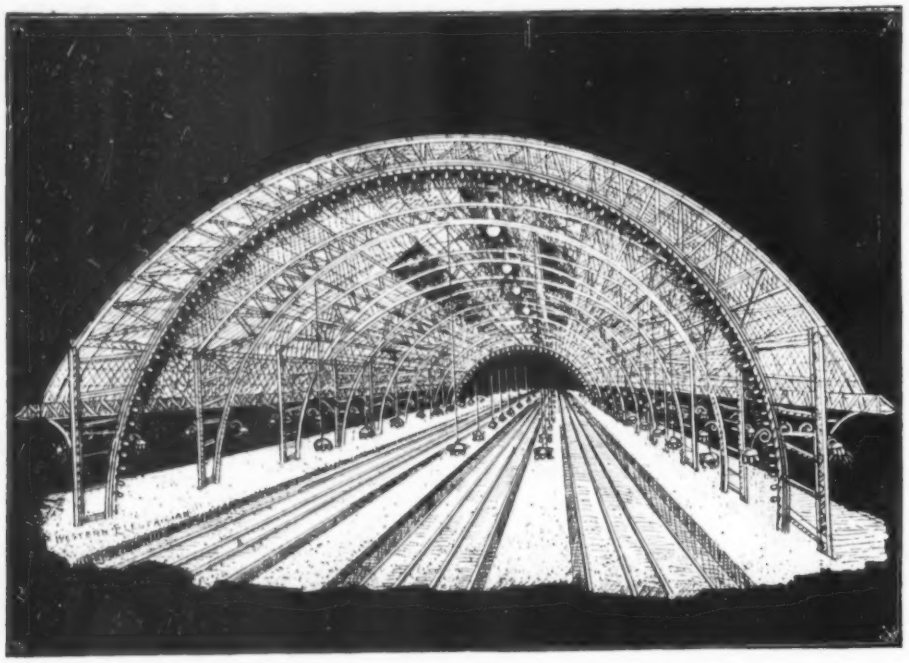


FIG. 1.—TRAIN SHED OF THE GRAND CENTRAL PASSENGER STATION, CHICAGO.

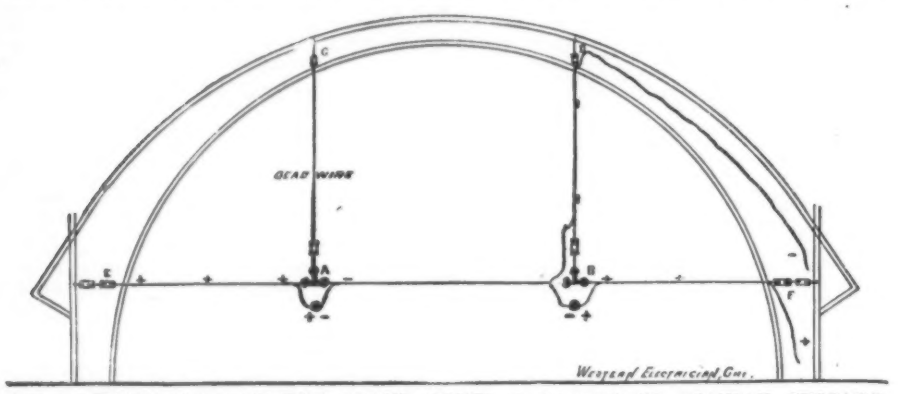



FIG. 2.—TRAIN SHED OF THE GRAND CENTRAL PASSENGER STATION, CHICAGO.

effect was much admired. As the installation has been pronounced one of the finest plants equipped in the West by the Edison company, the accompanying illustration, Fig. 1, showing the distribution of the lights in the train shed, will be of interest.

In the train shed there are 336 32-candle power lamps arranged in clusters. These lights are so wired that they may be lighted in ten sections from the dispatcher's office. In this way the shed may be illuminated according to the position of any particular train. The south and north arches of the train shed are each illuminated by 90 32-candle power lamps. The train shed has in all 14 arches, and the suspended clusters are wired as represented diagrammatically in the sectional view, Fig. 2. The method of wiring the clusters is a special one, and was devised to reduce the danger of short circuits to a minimum. Bearing in mind that bare copper conductors were employed, on account of the deleterious effects of the sulphurous fumes from the engines, the method of wiring will be readily understood. In the cut A, B, C and D are double and triple porcelain insulators respectively as indicated. Studying the cut closely it will be seen that the cross-over wires on both sides of the shed have the + sign, while the middle section is a conductor with a — sign. A little thought will now enable the reader to see the advantage of thus wiring an arch—a broken telegraph wire would have a poor chance of falling across two electric light wires which were not of the same sign, that is either say a + wire and another + wire or a — wire and a — wire. The plan of wiring the depot in this manner was devised by Lieut. F. B. Badt.—*Western Electrician.*

## THE MANNLICHER MAGAZINE RIFLE.

WE give engravings of the Mannlicher rifle, which has been very favorably spoken of on the Continent. The most striking feature of this arm is that it is not designed to be used as a single loader. At all times the soldier uses his magazine, no matter how deliberately he may take aim. If the cartridges had to be placed in the magazine one at a time there would be no gain of speed in this arrangement, but rather the contrary, for it is a slower operation to put a cartridge into a magazine and then transfer it to the barrel than to put it direct into the chamber. But, instead of being issued singly to the soldier, the cartridges are sent out in packages of five (Fig. 6), held together by a light steel clip (Fig. 7), and the whole five, with the holder, are placed in the magazine with more ease than one, since they present a better finger hold. At each backward and forward motion of the bolt a cartridge is pushed out of its holder, forced into the barrel and extracted, and as soon as the last has been removed, the holder drops through a hole in the bottom of the magazine and falls on the ground.

Another point of interest is that the bolt has no turning motion on its axis. It is pushed straight in and out, and is locked by a drop catch. The moment it is home the catch takes against a fixed projection in the body, which resists the rearward action of the powder pressure. The first action of drawing back the handle of the bolt is to lift the drop catch over the projection, when the bolt can be readily withdrawn, bringing the empty cartridge case with it. All the parts of the bolt (Figs. 2 to 5) can be taken apart without tools, with the assistance of a small rod which is firmly attached to the stock in the position usually occupied by the cleaning rod. The magazine is not intended to be removed, and is fitted with a spring, the platform of which always remains parallel to the cartridges, and directs their points to enter the chamber.

Fig. 1 shows the body of the rifle with the bolt drawn back. The top cartridge in the magazine can be seen standing ready to be driven into the chamber. When the bolt is moved forward its round end (Fig. 3), beyond which the extractor projects (Fig. 1), catches the base of the cartridge standing in the clip or cartridge holder (Fig. 6). Before the cartridge is free from the clip the bullet is entirely within the chamber, and forms a guide to lead it forward. When the clip ceases to hold the rear end of the cartridge, the extractor catches it and presses it against the hollowed side of the body, along which it slides into its place. There is no chance of a jam taking place, however fast the feeding may be effected, since the cartridge is held both at front and rear. The magazine spring lies partly within the steel clip without touching it. As soon as one cartridge is removed the remainder are all pushed up, the pressure of the upper cartridge against the turned-in sides of the holder supporting the latter; as soon as the last cartridge is put into the barrel this pressure is of course withdrawn, and the empty holder drops down, leaving a clear space for the insertion of another. The spring is formed of two blades: the lower is pivoted near the bottom of the magazine by one of the screws shown (Fig. 1), while the second is pivoted to the first. At each joint there is a strong spring of considerable range, so that the cartridges are pressed up steadily and firmly to the very last. This pressure is resisted by a catch or rib on the back of the holder (Fig. 6), which takes against a small catch, provided with an external pressing piece at the back of the magazine. This piece cannot be seen in the engravings.

The bolt is made in two pieces, the main part being bored from end to end. In its center lies the striker with the mainspring (Fig. 4), and in a groove in its side is the extractor (Fig. 5). The front end of the bolt is closed by a screw, having a small hole in it for the striker to pass through. In the head of this screw is a gate which receives the extractor. By this means the screw is locked and cannot chatter back. Into the back of the bolt there slides the handle, the two being held together by the striker and spring, as by an elastic bolt. To the end of the striker is screwed the cocking catch, which engages with a sear on the trigger. On the under side of the handle piece is a fixed incline, which the mainspring constantly tends to draw in between the bolt and the drop catch on the latter. This action, however, cannot take place until the bolt has been pressed in so far that the drop piece (Fig. 3) has arrived over a cavity cut in the gun body to receive it. Immediately this position is attained the handle piece can be pushed forward to lock the bolt. At the same time the cocking catch hooks on the sear, and the piece is cocked ready for firing. In extracting, the handle is first drawn back to lift the drop catch over the projection; during this time the bolt stands still. Further motion carries the bolt back, and with it the extractor and the cartridge.

It will be noticed that the extracting motion is done with a straight pull, aided by the hammering action which results from the handle starting in advance of the bolt. It appears to us that this is the weakest point in the rifle, and we much prefer the cam motion in bolt actions such as in the German Mauser. We see no reason, however, why the hammering motion should not be made greater, and we believe there are several very successful rifles with percussion extractors. The method of working with five cartridges in the magazine does not give a very great reserve for the "supreme moment" of which we hear so much, but it is contended that it forms quite as large a store as a man can make use of. After he has fired five shots in quick succession his aim has gone so wild that he would probably waste the remainder of his stock if it were any larger. The slight relief to the muscles from the change of attitude in putting a fresh supply into the magazine will enable him to start afresh with greater precision, which will more than recoup for the second or two that will be wasted. Since the gun is not intended to be used as a single loader, it may happen, however, that the supreme moment will find the man with only one or two cartridges in his magazine. He may have ceased firing for some time, when suddenly a furious rush upon his position is made by a superior force. Probably he has forgotten how many of his cartridges have been expended, and cannot tell how many remain. Yet it is most important that he should have a full supply ready against the command to fire is given. Under these conditions, a very ingenious device is brought into play; the catch at the back of the magazine is pressed, and immediately the holder, with all the cartridges it contains, springs out and leaves the magazine empty. A new holder is then inserted, and the man starts with a full store, and can pour in his

FIG. 1.

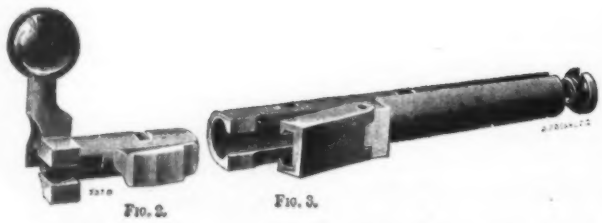


FIG. 2. FIG. 3.

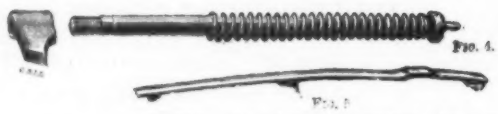


FIG. 4.

FIG. 5.

FIG. 6.

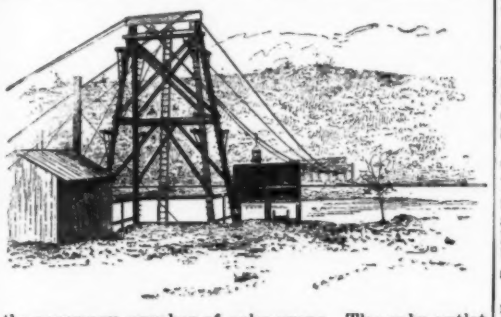
FIG. 7.

THE MANNLICHER MAGAZINE RIFLE.

five shots with rapidity and precision. For a continuous rapid fire the Mannlicher clip system is undoubtedly far superior to a magazine which may hold ten cartridges, but which has to be loaded one by one, and, moreover, it does away with the complication of a "cut-off." The great rapidity with which the clips of cartridges can be inserted does away with the necessity of carrying a large store of cartridges in the magazine. We must add in conclusion that the diameter of the bullet is 0·320 in., and that the weapon has been adopted by the Austrian government, the magazine principle by the German government, and the French, we hear, are adopting a similar system for their cavalry.—*Engineering.*

## THE RAINEY BANK TRAMWAY.

THE accompanying engraving illustrates a suspended wire rope tramway, across the Youghiogheny River near Connellsville, recently erected for the Rainey Bank Coal and Coke Company. The coal mines at this place are located on the bluff on the west side of the river, and the contour of the ground there was such that there was no space available for the erection of



the necessary number of coke ovens. The only outlet for the mines was on the opposite side of the river. A bridge across the stream would have been too expensive, and consequently the plan of a suspended wire rope tramway was adopted as a cheaper and equally efficient method of transportation.

The requirements of the plant being too great for one cable, the tramway was installed with a double system. The two cables are anchored on one side of the river in one of the mine drifts and on the other in masonry, around which the cables are turned. The cables are each two inches in diameter, the span being 1,000 feet. The cables are close together at the loading end and about 30 feet apart at the discharging, allowing a free passage of the buckets in the middle.

The haulage rope is an endless steel wire rope five-eighths of an inch in diameter. It passes around a grip wheel of peculiar construction, keyed to the crank shaft of the engine on the east side of the river, thence it passes over the sheaves in the tower, across the river and around the sheave in the other tower. The buckets are two in number, each of 2½ tons capacity, 4 feet in diameter and 6 feet deep. They discharge automatically by a striking lever, the hinged bottoms returning to place by counterweights, and are held in position by strong hooks.

The tower on the west side of the river is 40 feet higher than that on the east side, and the loaded buckets run down the incline by gravity. Buckets are loading and discharging at the same time and the engine is reversed for alternate trips.

The trip of each bucket is made in 30 seconds, and with the time occupied in loading and discharging, it is estimated that the total capacity of the tramway is 750 tons per day of ten hours, at an expense not exceeding three cents per ton. The tramway was designed and erected by Mr. F. H. McDowell, of the Union Wire Rope Tramway Company, 117 Liberty Street, New York.—*Engineering and Mining Journal.*

## SERVICE FROM LA GOULETTE TO TUNIS BY BOAT.

As our readers know, it is impossible to land passengers and goods destined for Tunis directly at that city. The latter, in fact, is situated on the edge of a salt water lake eleven miles in circumference and six and a half feet in depth, that communicates with the Mediterranean through a narrow canal impracticable to ships, and the outer extremity of which is occupied by the port of La Goulette. Traders and goods, therefore, have to be put on shore at this port. The distance between the two cities is ten miles.

A railway line exploited by the Italian Rubatino Company puts them in communication, and carries the passengers. This it does at a very high charge, and with a slowness that is often aggravating, certain trains taking more than an hour to make the journey. As for merchandise, heavy vessels called "mahones" take that aboard, and, entering the canal, arrive at their destination whenever they can. Upon the whole, as may be seen, this important service leaves much to be desired and is performed under the worst conditions of regularity.

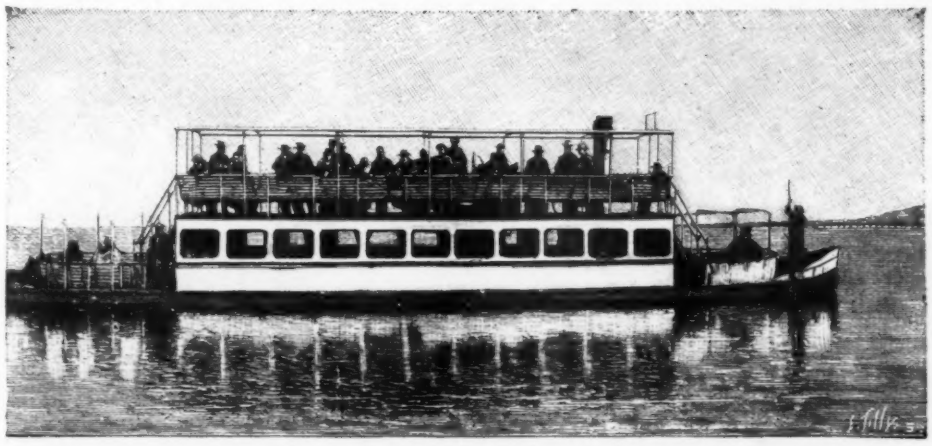
So it was with great satisfaction that those interested welcomed the advent of the new Compagnie Franco-Tunisienne de Transports. This company is rather a private association. It consists of fifteen members, all of them Frenchmen, who have put up the necessary capital. Among them we may mention Messrs. Dautresme, Ossude & Anson, the delegated administrators. The direction of the service is confided to Mr. Advis, a former commander of the packet boat Ville de Brest, of the Compagnie Generale Transatlantique.

The company proposes to do all the carrying of passengers and goods between La Goulette and Tunis. Up to the present, only the passenger service has been organized, but the merchandise service will soon follow. The boats serving for such transportation are ready and the towboat that the company is having built will be ready before long. We give a view of the steamer, which is now making four trips daily between the two ports.

It is 68 feet long by 11½ feet in breadth, and is capable of carrying 120 passengers, 72 of them upon the deck. The management is well conceived and the installation very comfortable. It is provided with a new style of engine, capable of developing a great power (100 horse), under a very small bulk, and built at the Saint Denis Works, Paris.

The company has every chance of success before it. The cost of the trip is about a third less than by the Rubino Railway, and the mode of locomotion by water is certainly more agreeable than a trip by car, especially during summer. Finally, there will be nothing left to be desired when, before long, the towboat will be regularly bringing to Tunis the merchandise transshipped at La Goulette upon the company's lighters.

In a few days a second boat for passengers will be making the trip concurrently with the other.—*L'Illustration.*



NEW BOAT FOR CARRYING PASSENGERS BETWEEN LA GOULETTE AND TUNIS.

## A STEERING SCREW PROPELLER.

THAT the screw propeller in ordinary use is capable of improvement is, of course, a hard fact, and any suggestion which will tend to remove its present disadvantages will always be welcome.

We have had brought under our notice a modification of the present arrangement, which appears to offer sufficient features of interest to justify us in laying them before our readers.

Among the disadvantages attached to the ordinary screw propeller are the active resistance it offers to the maneuvering of the vessel and the consequent waste of power and loss of speed; the inequality of strain on the blades during such maneuvering, and the accompanying vibration and jarring.

In the propeller now under consideration the shaft

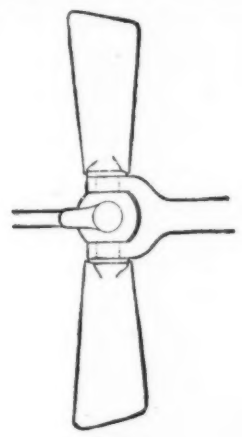


FIG. 1.

terminates in a universal joint which connects it with a smaller shaft, or, more properly speaking, an extension of itself. The center—or connecting—piece of this joint is taken as the base from which the propeller blades spring, and to which they are rigidly fixed. In the case of a two-bladed screw, the blades are best attached to the center piece at those points where it is held by the two arms of the main shaft. Fig. 1 shows a sketch of this propeller, and is intended to illustrate the principle of the invention rather than its detail.

It seems clear that the pitches of the blades can be altered to any extent by changing the position of the shaft extension, and that any increase in the pitch of one blade is accompanied by a corresponding decrease in that of the other. For the present purpose, however, the movements of the shaft extension must be confined to the horizontal plane in which the main shaft lies. The methods of supporting this extension may be varied, but we will at present only describe one—that shown in Fig. 2. It will be

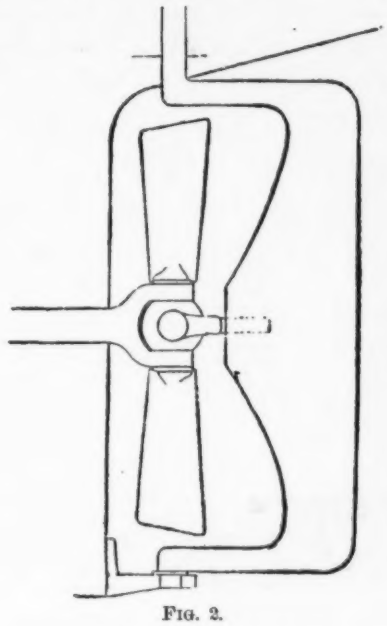


FIG. 2.

seen that a vertical frame is supported at two points, one directly above and the other directly beneath the center of the joint. This frame is at liberty to swing horizontally from side to side at the rear of the screw. It carries the end of the extension in a circular bore cut in its central part.

In a horizontal plane the extension can thus move with the frame, and at the same time be at liberty to follow the rotary motion imparted to it by the main shaft. In order to give it stability in the water and enable it to act as a rudder when the screw is not working, the rear part of this supporting frame is made deep from front to back, and is manipulated from deck in the same way as an ordinary rudder.

This coupling of the extension supporting frame and the rudder, this as it were Siamese twins arrangement, seems to offer some considerations worthy of study. The maneuvering power of the vessel seems to be greatly increased, its stability in its course is not affected, the shaft extension, therefore the "feathering," being under complete control, while no power is lost or wasted, as the "feathering" equalizes the strain upon the blades and thus enables the screw to do its full work.

When we come to consider this matter of the "feathering" of the blades, we find that when the vessel is turning, the propeller is, of course, passing obliquely through the water. This is tantamount to saying that the water meets the screw obliquely; and the illustration (Fig. 3) shows that under these conditions the

Fig 3

"feathering" of the blades is practically automatic. In this horizontal plan the vessel is supposed to be turning to the right and the blades to be in a vertical position.

Suppose also that the extension is entirely removed from the propeller. Let E F represent the main shaft, A B the upper blade, C D the lower blade, and the arrows the direction in which the water meets the propeller. Then it is clear that the blades would have a tendency to arrange themselves so that the angle which the arrows make with each blade should be the same. They would, therefore, when vertical, be in the position here shown. Similarly, when the blades are horizontal, they have a tendency to become of equal pitch, for the direction in which the water meets the screw is in the same horizontal plane with the blades. Its obliquity in that plane has no influence on the "feathering."

Now the two positions which have just been shown to be natural to the blades when the vessel is turning

to the right are identical with those which the extension, if moved to the right, would impart to them; and in the same way it can be shown that in moving from the horizontal to the vertical position, and *vice versa*, the blades would naturally vary in pitch in the same manner and degree as when guided by the extension. This "feathering," therefore, becomes automatic after the first momentary effort necessary to produce a change in the course of the vessel. The same can be shown to be the case when the vessel is turning to the left, and the demonstration is equally applicable, whether the vessel be going ahead or astern.

In the four-bladed propeller the blades are fixed to the center piece of the joint at its four bearing points. Two of its blades therefore occupy the same positions as those of the propeller shown in Fig. 1, and revolve in a plane at right angles to the main shaft. The two additional blades, however, revolve in a plane which is always at right angles to the shaft extension, and in that plane they "feather" with the same effect as the two original blades. For if the shaft extension be moved to the right, the pitch of the upper of the two additional blades is reduced, and that of the lower increased, the moment of greatest variation being when the blades are vertical. (These variations in pitch must, of course, be considered relatively to the plane in which the blades are working.) When the two blades are horizontal, the pitch of one is equal to that of the other. It is thus seen that these two blades tend to change the direction of the vessel to the right, and that the steering effect is greatest when they are in a horizontal position. A similar effect is, however, produced by the two original blades when in a vertical position. The four blades are, therefore, at any moment working in harmony and with precisely similar effects. This may also be shown to be the case when the extension is moved to the left, and when the vessel is going astern. In a three-bladed screw, one blade may be in the same position as either of those in Fig. 1. The two others are then fixed to the center piece of the joint at equal intervals from one another, and from the first, the base centers of all three being in the plane which passes through the four bearing points of the joint, so that when the extension is in the same straight line with the main shaft, the plane of revolution of the blades is perpendicular to that straight line. The steering effect of the first blade is due to its "feathering," and that of the two others to a motion derived partly from "feathering" and partly from the inclined position of the plane of revolution, and it will be found that the three blades work in concert similarly to those of the four-bladed propeller.

With this method of steering it should be stated that there is no vibration in turning, and no speed lost, as is the case where the rudder alone is used for steering. Again, as no power is transmitted through the joint, it is subjected to no strain, and is therefore not liable to get out of order, while the "feathering" being, as we have said, all but automatic, there can be little strain on the extension. The mechanism and working of the propeller being simple and natural, and no part being subjected to any undue strain, the wear and tear is therefore reduced to a minimum. Lastly, the blades being rigidly fixed to the center piece of the joint, and therefore to one another, are as firmly and strongly based as in the ordinary screw propeller. It should be mentioned that, although many different forms of joint may be used, they each and all must embody the principle of Hooke's universal joint.

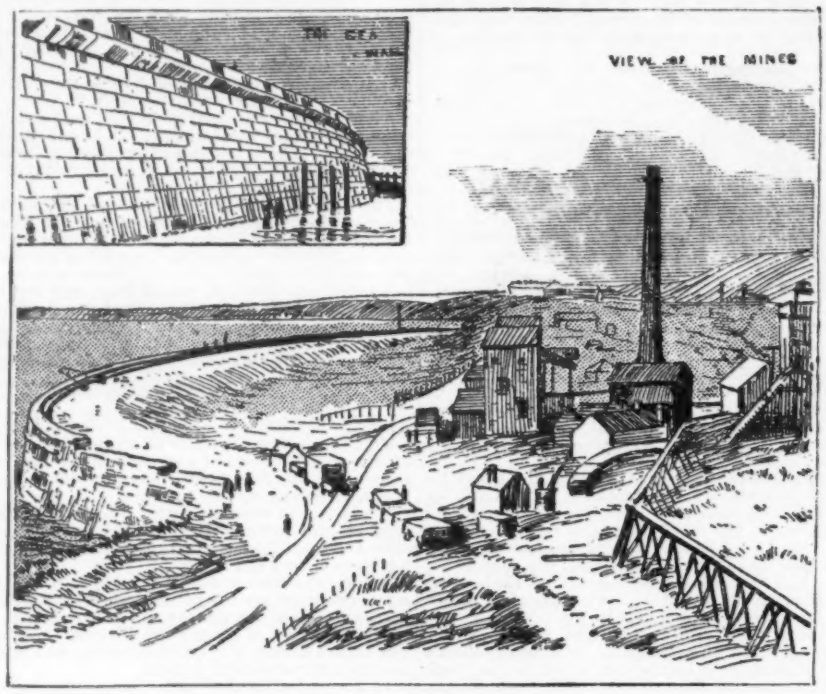
Two other methods of connecting the rudder and the shaft extension other than we have described have, we believe, been designed. In one, the ordinary rudder has been detained in its place behind the propeller, the extension support (but not so deep from front to back as shown in Fig. 2) and the rudder being linked together on deck. In the other plan, the ordinary rudder is discarded, but the extension support, acting as a rudder, swings about a vertical line *behind* the center of the joint, and so carries the extension through a smaller angle than that through which it moves itself.

To all craft requiring to navigate crowded or intricate water-ways, the propeller we have described should offer many advantages. It seems to differ in some essential points from every other designed with the same object in view, not the least important of which lies in its simplicity.

The credit of the invention is due to Mr. F. H. White, of London.—*Marine Engineer.*

## SEA WALL TO PROTECT IRON ORE MINING OPERATIONS.

THE great sea barrier across a portion of the Duddon Estuary, in Cumberland, which has been built by Sir John Coode for the Hodbarrow Mining Company, to enable the excavation of red hematite iron ore to be carried on underneath the sea bed, is a massive and substantial structure, unique in character, inasmuch as it is at one and the same time a breakwater and a water-tight dam. It presents an imposing appearance, being two-thirds of a mile in length, for the greater




A MINING SEA WALL.

part of which distance the height from the foundations to the top of the sea wall is fully fifty feet. At high water during spring tides there is a depth of more than twenty feet on the seaward face of the work, the sea often in southwesterly gales breaking against it with great violence. The work was undertaken by the mining company because on land the ore had been excavated as close to the sea margin as it was possible to work without letting down the fringing surface of the land and admitting an influx of the sea, drowning the mine.—*Daily Graphic.*

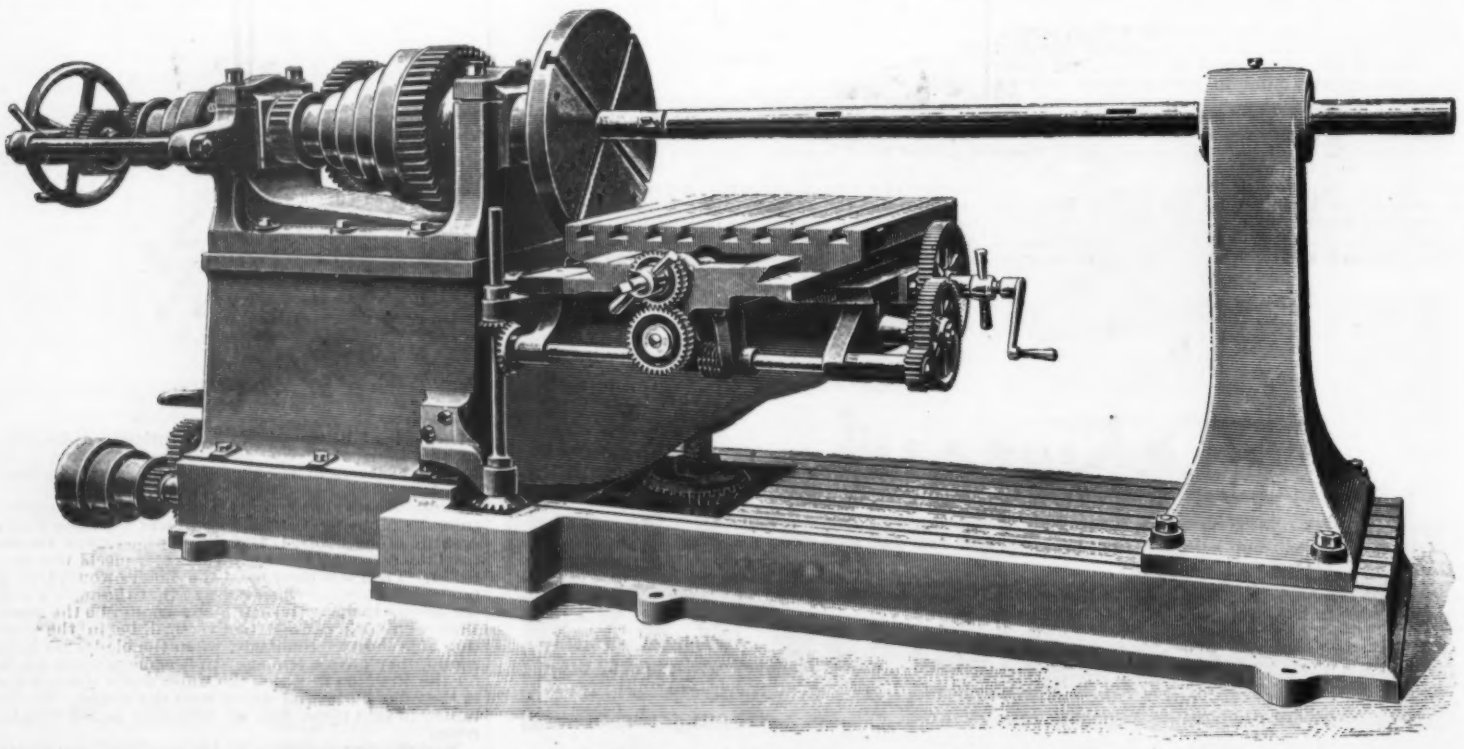
## BORING AND CHUCK LATHE.

THE lathe shown below is designed so that when large castings are to be operated upon they can be placed upon the foundation plate. The fast headstock is arranged with a steel spindle inclosed in a cast iron barrel, and is fitted with self-acting feed motion, with three changes of speed, giving a traverse of 20 inches to the boring bar, the outer end of which is supported by a strong standard. A quick withdraw motion is secured by a hand wheel at the end of headstock. The machine will admit 18 inches from center of boring bar to top of table at its lowest position. The table has a transverse traverse of 24 inches and a longitudinal traverse of 6 inches, or of 10 inches when the face plate is not in use, and this can be further increased by removing the wheels at the top of the knee bracket. The vertical, transverse, and longitudinal motions of table are self-acting. The makers are the Northern Engineering Company, limited, Halifax.—*Industries.*

## HEATING CARS WITH THE THERMO-SIPHON.

THE heating of railway cars is a question that the severity of the winter of 1890-91 rendered of vital interest, and, under the pressure of a general demand, the companies that were still running short distance trains without heat were obliged to introduce heat into all the cars and all the trains. In the first and second class cars are retained, as a general thing, the ordinary hot water foot warmers, despite the numerous manipulations that they have the inconvenience of requiring.

For the reheating of these foot warmers, it is necessary, besides, to have numerous boilers located along the line, and this is the main difficulty that has hitherto stood in the way of heating trains that run short distances, for it often happens that as the extreme stations are of slight importance, they have no heating installation. From this point of view, it is regrettable that the application of acetate of soda foot warmers has not been further developed, for the use of this salt permits of keeping the warmers hot for a much longer time (five or six hours instead of two), and the manipulations are thus diminished, while at the same



IMPROVED HORIZONTAL BORING AND CHUCK LATHE.

time it is possible to reduce the number of heating installations along the line.

However this may be, in order to somewhat diminish the manipulations of the ordinary warmers, the railway companies, as a general thing, as above stated, limit the application of them to first and second class cars, and to the third class ones apply different processes, such as the use of stoves, heating by hot air with briquettes, etc.

The state railways in particular have applied to the cars of all classes of large size mounted on bogies a process of heating by thermosiphons, which, for passengers, presents the advantage of preserving the ordinary heaters, while at the same time doing away with the manipulations. This apparatus, elaborated by Mr. Gallet, of Tours, from ideas furnished by Mr. Parent, engineer in chief of *materiel* and traction, was applied upon the bogie cars which this administration sent to the exposition of 1889. It presents some important advantages which render it particularly recommendable, and we have thought that it would prove of interest to give a description of it, from an article published in the *Revue Generale des Chemins de Fer.*

The apparatus consists of boilers fixed under the frame of each car that distribute hot water among foot warmers placed transversely in each compartment, under the feet of the passengers.

Fig. 1 gives a view and section of these boilers, and Fig. 2 gives a general view of the installation at the extremity of the car frame. As may be seen in Fig. 1, the boiler is tubular and consists of two saddle-back sections connected by a series of vertical tubes. It thus constitutes a sort of tube with open-work walls, into which is introduced a brazier filled with burning coke. The entire affair is surrounded by a horizontal jacket with solid walls provided beneath with draught tubulures. Those seen in Fig. 1 are provided with conical cut-offs for regulating the draught, and which are mounted upon a hollow iron shaft maneuvered from the outside by a lever provided with a spring that engages in the apertures of the sector observed at the bottom of the boiler jacket, thus permitting of fixing the position of it according to the draught of air desired. The gases of combustion escape through the upper orifice in the jacket. This orifice is so directed that no emanations can enter through the doors of the cars placed behind the one that carries the boiler. The jacket is closed by doors at the extremities locked by a key to prevent the incandescent coke from escaping. The boiler is provided with a blow-off cock. The hot water issuing from the boiler enters a conduit, B (Fig. 2), that runs throughout the length of the train, and whence it is led to the warmers by pipes, as shown in Fig. 1. The connections have joints provided with rubber rings, in order to permit of the sliding of the pipes produced by expansion and the suspension of the box. These junctions end at chambers situated at one of the extremities of heaters containing fifteen steel tubes. The water circulates therein and gives up its heat to the sides of the tubes, and is led back to the boiler by a return pipe, A (Fig. 2), which debouches at the lower part of the boiler, so that there is established a continuous circulation between the latter and the heaters.

For disposing of the gases and vapors on issuing from the boiler there is arranged upon the distributing conduit a small tube that debouches into a special box, arranged above B, forming an expansion chamber. An analogous box, seen above A, in the section of the car, communicates with the return conduit for the feeding and storage of water.

The tubes and the heaters and boilers are of steel riveted to steel heads, in order to facilitate expansion. They are 10 millimeters in diameter and 1·5 millimeters in thickness. They are tested cold under a pressure of 10 kilogrammes, and hot at the temperature of ebullition.

It will be seen from this description that the manipulation is reduced to regulation and to the keeping up of the fire, and is effected from the outside, without its being necessary to enter the car. The grates are charged with turf charcoal, which burns slowly, and the supply suffices to assure a heating for eighteen consecutive hours. Owing to the regulating cones mentioned above, the draught of air can be varied according to needs, a regular combustion can be obtained, and consequently a very regular heating. The products of combustion escape freely at a temperature that does not exceed 75°, and are so directed that they cannot produce any accident in the passengers' compartments.

As may be seen, this style of thermosiphon secures a regular heating without requiring any manipulations in the interior of the cars, and without being attended with any danger of fire or asphyxia.

From the standpoint of the rolling stock, it has the advantage of being capable of being easily installed without requiring any modification of the types in use. It can be dismounted in summer in order to diminish the dead weight, and can be kept in repair at slight expense.—*La Nature.*

## DR. OTTO AND HIS INVENTION.

THE name of Dr. Nicolaus August Otto is known all over the civilized world as the inventor of the first economical and commercially successful gas engine. In fact, he may be called the inventor of the gas engine in the same sense, and with as much right, as James Watt is commonly called the inventor of the steam engine. There were steam engines in existence before Watt, working with a waste of steam and fuel that would make even a colliery owner's hair stand on end at the present day, such engines being possible only at the pit's mouth, and at a time when coal was extremely cheap. Watt's invention consisted mainly in transferring the condensation from the cylinder to a separate condenser, which again rendered the omission of condensation possible, and led to the ordinary high pressure engine. The economy in steam and fuel resulting from these changes rendered the employment of steam engines generally possible, and led to the industrial development of the present century, and the credit of this is justly accorded to James Watt. In the same way, Otto, by arranging the ignition and combustion of the gas in a manner resulting in an enormous economy of gas compared with previous gas engines, transformed a wasteful into an economical engine, and led the way to its extensive adoption.

DR. NICOLAUS AUGUST OTTO.

The difficulties of a scientific appreciation of the explosion and combustion processes in a gas engine are exceedingly great, in consequence of the high temperature and short time in which they are completed, which makes it the more remarkable that success should have been achieved in this line by a man who had neither received a scientific or technical training, nor was brought in contact with such matters in his ordinary avocation. Otto, who was born in 1832, at Holzhausen, Nassau, was occupied in purely commercial matters to his twenty-ninth year, though having a taste for natural sciences he acquired an extensive insight into physical questions. When in 1861 the news arrived that Lenoir had succeeded in producing motive power by the explosion of illuminating gas, he devoted his thoughts to the same subject, and undeterred by the fact that the irregularly-acting Lenoir engine was far from being a practical success, left his secure position and devoted himself to the working out of his ideas as soon as he thought he had found the right way. In 1863 he got his first engine made by a machinist at Cologne, the result of which was little satisfactory, as Otto at that time had hardly any knowledge of machine construction. He got into difficulties and despondency, when he had the good fortune to meet with Mr. Eugen Langen, a member of one of the principal manufacturers' families at Cologne, and to inspire him with his own confidence in the future of the gas engine. Mr. Langen was a thoroughly-trained mechanical engineer and skillful designer of machinery, and putting Otto's ideas into a good form, they produced the atmospheric gas engine in 1864, which proved a success almost from the beginning.

At the Paris exhibition the three then existing gas engines—Lenoir's, Hugon's, and Otto and Langen's—were tested as to their efficiency, when the consumption of gas in these engines was found to be in the ratio of 10:6:4, and the prize was awarded to the latter, although at first the jury had been inclined to ignore it altogether on account of its noisy working. This testimonial led to a rapid extension of business. In 1869 the works were removed from their old premises in a room in Langen's sugar refinery to new premises at Dentz, and in 1871 the firm was converted into a joint stock company. That the new motor met an extensive want is evident from the fact that notwithstanding all its deficiencies, above 5,000 of such atmospheric gas engines were built, of a quarter to three horse power. Otto himself had by this time acquired a knowledge of mechanical engineering, and was continually occupied in exploring doubtful questions by extensive experiments. A room at the Dentz works is a kind of museum, containing a series of different engines studied, tested, and abandoned, and showing the gradual development of the direct-acting gas engine at present known by Otto's name.

By introducing the four-stroke cycle he succeeded in using the power cylinder as compressor, and arriving at a simple construction of engine ingeniously designed in many of its parts, which has remained substantially the same during the fifteen years that have since elapsed, and most other engineers occupying themselves with gas engines have ultimately adopted essentially the same construction. But the merit of his invention does not lie in this so much as in the arrangement of the combustion and ignition, by which the consumption of gas was reduced to less than one-half, and an advance made that placed the gas engine into the ranks as a competitor with the steam engine in respect of economy.

The four-stroke principle had been indicated, though not carried out before. The advantage of compression and increased speed alone would not have reached the same result. From the pamphlet issued on the twenty-fifth anniversary of the establishment of the factory at Dentz, which probably contains Otto's own remarks, we cull the following history of the development of his invention:

In endeavoring to bring out a direct-acting gas engine the atmospheric engine formed an object of study and experiment for Dr. Otto. The effect of each explosion is clearly visible in this engine, as the piston can rise unimpeded. According to the richness of the gas and air mixture, the piston rose quickly or slowly; with poor mixtures only after a certain time, during which the flywheel had made some turns, and very slowly. Otto recognized from this that poor mixtures burn slowly, but are difficult to ignite, and also

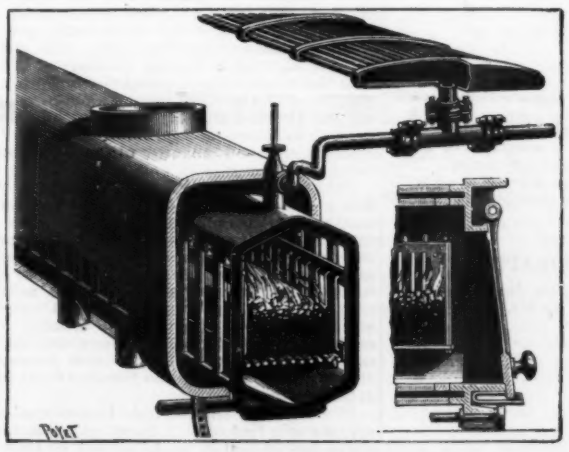


FIG. 1.—BOILER FOR HEATING RAILWAY CARS.

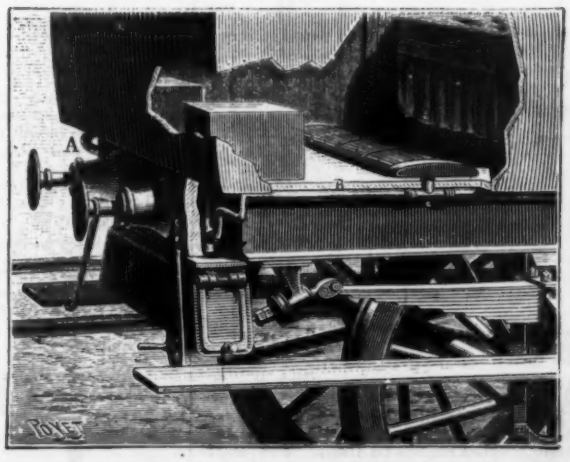


FIG. 2.—GENERAL VIEW OF THE INSTALLATION.

that a motor free from shocks could only be obtained by using poor mixtures.

The problem then reduced itself to the question: How can poor mixtures of 1:11 to 1:13 be ignited with certainty? The problem occupied him for years, till one day when regarding the smoke issuing from the factory chimney its solution presented itself. The gas mixture must be made like that of smoke and air, dense at the issue from the chimney and gradually diluted in the air.

If freedom from shocks can only be obtained from mixtures of gas and air in the ratio of one to twelve, and these will not ignite, the problem can be solved by first drawing 5, 4, or 3 parts of air and then mixtures of gas and air in the ratio of 1:7, 1:8, 1:9, the total will then be 1:12, while at the point of ignition a sufficiently rich mixture will be found. It is in this production of layers of mixtures of various and increasing richness that the kernel of Otto's invention is to be found. It resulted in an improved thermal effect, slower combustion, and a greater abscrption of heat by the cylinder walls, without which the temperature would have ri-en to a height destructive of all lubricants and metals.

It must be regarded as a fortunate incident that simultaneously with the gas engine the use of mineral oils as lubricants, capable of standing great heat, was discovered. Without the latter the progress of the engine would have been much retarded.

Dr. Otto himself explained the principle of combustion in his engine to Dr. Ilsby, whose obituary notice in the *Journal of the Society of German Engineers* we have utilized for this article, in the following manner: If I wanted to set a house of several stories on fire, without a chance of its being extinguished, I should take care to fill the lower stories with good combustible matter, without troubling myself much about the upper stories, and fill the lobbies and stairs with straw and rags soaked with petroleum. This is what has been done in the gas engine.

Another simile would be that of a cartridge filled with a slowly exploding substance ignited by a highly explosive substance at one end.

Of the personal circumstances of Dr. Otto's life there is little to be recorded. It was passed quietly in his labors and his family circle. He was of a retiring, almost shy, disposition, and certainly did not seek for honors.

When the Society of German Engineers held its annual meeting at Cologne, in 1887, he absented himself from all meetings and festivities for fear of receiving a public laudation. Nevertheless, he was much pleased when the Wurzburg University conferred on him the honorary doctor's degree, an honor rarely accorded to an engineer, either abroad or here, though its conferment, in our opinion, on eminent engineers is much more deserved and warranted than on successful politicians. However, without any official acknowledgment, his name will survive as the author of one of the most important inventions of this century.—*Mechanical World.*

## PHOTOGRAPHY OF JETS AND BURSTING SOAP FILMS.

OWING to the kindness of Lord Rayleigh in lending the original photographs, we are enabled now to give outline illustrations, photographically produced upon the blocks for the sake of accuracy, of some of his results in what the Americans call "lightning" photography. The substance of his lecture a fortnight ago at the Royal Institution on the subject was published in these pages recently.

Fig. 1 represents a jet of air blown up through water, and photographed by the electric spark; in this case it will be noticed that the jet breaks into bubbles close to the nozzle of the pipe.

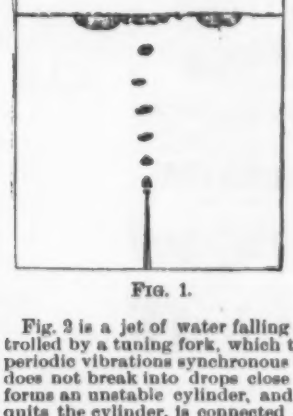


FIG. 1.

FIG. 2.

Fig. 2 is a jet of water falling vertically in air, controlled by a tuning fork, which throws the object into periodic vibrations synchronous to itself. The water does not break into drops close to the nozzle; it first forms an unstable cylinder, and each drop, before it quits the cylinder, is connected with it by a ligament. This ligament gathers itself into a little drop, which travels faster than the large one before it, and sometimes catches it and "cannons" with it.

Fig. 3 represents the plan adopted to burst a soap film while it is illuminated by an electric spark; the duration of the latter is about the $\frac{1}{1000000}$ of a second; the rupture of the soap film occupies about $\frac{1}{1000}$ of a second, and these two events have to be made to occur together. A bullet is held against a piece of wood by a spring; to the spring a piece of soft iron attached; when the latter is attracted by an electromagnet, the spring is pulled back and the bullet falls.

Two pieces of apparatus like this are employed, so that when an electrical current is sent, two bullets fall at the same instant; the one ruptures the film, the other completes the electric circuit sufficiently to allow the spark to pass.

Fig. 4 represents a soap film in the first stage of disruption, Fig. 5 in the second stage of disruption, and Fig. 6 in the third stage. The falling bullets are photographed in each case. The shots at the moment of touching the film had attained a velocity of about

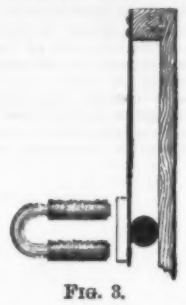


FIG. 3.

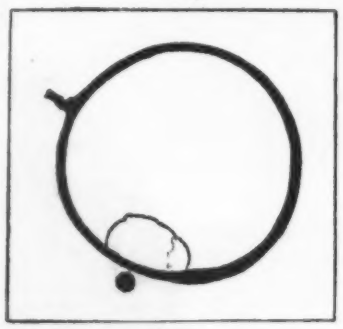


FIG. 4.

FIG. 5.

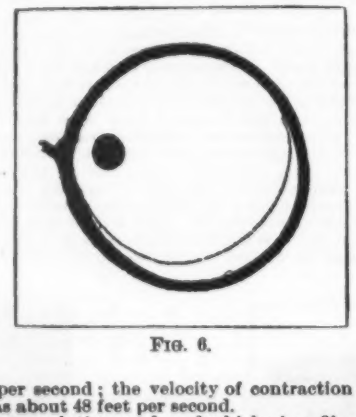


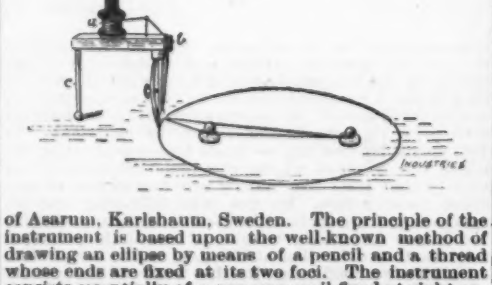
FIG. 6.

8 feet per second; the velocity of contraction of each film was about 48 feet per second.

The soap solution used, and which gives films of considerable durability, consisted of a solution of 3 per cent. oleate of soda and 25 per cent. glycerine. The iron wire rings supporting the films were coated with solid paraffin; the films are more durable when supported by paraffin.—*Photo. News.*

## A SIMPLE ELLIPTOGRAPH.

THE illustration represents a little instrument for drawing figures of elliptical form, by Mr. C. E. Egner,



of Asarum, Karlshaum, Sweden. The principle of the instrument is based upon the well-known method of drawing an ellipse by means of a pencil and a thread whose ends are fixed at its two foci. The instrument consists essentially of a pen or pencil fixed at right angles to a small horizontal bar, at the other end of which is similarly provided a leg, *c*, with a ball point which acts as a rest. On the top of the bar a vertical handle, with a small reel, *a* (containing a double thread), at its lower end, is mounted. This is revolved in order to lengthen or shorten the thread to suit the size of the ellipse to be drawn. The thread passes down practically to the point of the pen or pencil, and is held secure by the small thumb-screw, *b* (shown). The ball-headed pins are pressed into the paper at the foci of the required ellipse. The thread is placed around them, and the curve is then completed in the usual way. The instrument is provided with pen and pencil, legs and pins, and is neatly arranged in a small case.

## SPONTANEOUS COMBUSTION.

By ROBERT R. TATLOCK, F.R.S.E., F.I.C., F.C.S.

THE tendency of many carbonaceous substances, both of an organized and structureless character, to combine with oxygen, under ordinary conditions, with evolution of heat, has been made the subject of much patient investigation, and a large mass of information relating thereto is now available. Inquiries in this direction, however, have had reference chiefly to the circumstances under which this phenomenon takes place, and to its prevention, with the view of obviating the disastrous consequences which it involves, when the temperature rises sufficiently high to char or to inflame goods of value. Much obscurity, however, still hangs round the question of the nature of the products formed at the commencement and during the progress of the chemical action, and any work done with the object of throwing light on this point would probably be productive of valuable results. The observed slowness with which these substances combine with oxygen is more apparent than real, the time occupied being, not what is required for the action to take place, but rather what is necessary for the non-contiguous molecules to be brought into contact. There can be little doubt that if the ultimate molecules of these bodies were in contact with the necessary oxygen molecules in sufficient number, combination would be instantaneous, as in the case of metals in the pyrophoric condition.

Nor is it even known whether the comparatively small proportions of oxygen which take part in such action combine with the entire complex substance—an oil, for example—or only with some part of it, leaving the remainder intact. In some instances, however, the nature of the chemical changes has been very fully ascertained, as, for example, in the heating of barley in the process of malting, by which starch is converted into maltose and dextrin, with evolution of carbonic acid.

The conditions which favor this low combustion are well known; they are, first, the presence of the carbonaceous body, which must always be one that would burn in the ordinary sense if heated to redness in air; second, the presence of air or oxygen; third, the presence of moisture; and fourth, at least a moderate temperature. All these being fulfilled, the mechanical condition of the substance is of the greatest consequence, as, if it is either in a porous or spongy state, or in a condition of fine division, the facility for heating is greatly increased, while a calm and still atmosphere aid very materially. The following examples illustrate the varied conditions under which this heating frequently takes place, particularly with regard to the nature of the material. A fire broke out, apparently spontaneously, in a workshop in Glasgow where "fire lighters" were manufactured. These were prepared by mixing sawdust with melted resin in certain proportions.

On the following day some of the finished goods which had escaped injury were taken away for investigation. One pound weight of these were placed under a glass shade with a thermometer, and in less than an hour the substance burst into flame. An examination of the sawdust showed that it contained a large proportion of moisture when mixed with the resin, and further experiments confirmed the view that this was the cause of the accident. Again, a quantity of weaver's "heddles," prepared, as usual, with boiled linseed oil, were sent from a factory in this town to Aberdeen. The railway truck which carried the goods took fire, to all appearance spontaneously, and there could be no doubt, from a careful scrutiny of the whole case, that the oil was the cause of the mishap, as the center portion of the heddles, which alone was prepared with oil, was charred and carbonized, while the rest of the threads in the same bundle were intact. The same accident happened on two other occasions about the same time.

Yet another instance: A few hundred tons of dried fish guano were landed from a vessel at Glasgow harbor, and at once placed in bulk in a store with a stone floor. In a short time the material began to "heat" internally, in consequence of which it was opened out and spread more thinly over the floor by a gang of men, but while this was being done a large quantity of it suddenly took fire, and before the flames could be extinguished, a portion of the wooden beams of the ceiling was destroyed The spontaneous heating and consequent conflagration of coal cargoes, especially those of large size, are too familiar to us to require any reference.

If we assume that a cubic foot of coal weighs 75 lb., and a cubic foot of air 1·23 oz., and that for every three cubic feet of coal in hold, bunker, or store there is one cubic foot of air containing at least 0·28 oz. of oxygen, we have conditions equivalent to 2 cwt. of coal, having probably a surface of 50 sq. ft., practically in contact with the 0·28 oz. of oxygen, which, if it combined with carbon to form carbonic acid, would give out sufficient heat to raise the cubic foot of air from 60° F. to 5,316° F., which is much higher than the temperature of any blast furnace. Of course in practice this temperature could not be attained by the combustion of the oxygen initially present, as the heat would be partly communicated to the coal itself, and would partly escape with the warm air, for even if the atmosphere among the coal was dead still to begin with, the warmth imparted to it would cause it to expand, ascend, and pass away.

In order to determine satisfactorily whether it was the sulphur, the compressed or occluded gases, or the non-gaseous carbon compounds in coal that was responsible for spontaneous ignition, I took different

kinds of coal—cannel and house coal—pulverized them finely, and after exposing them to the air for twenty-four hours to allow all contained gases to escape, dried them thoroughly at 212 deg. F., and determined the percentage of sulphur existing as sulphuric acid in each. A weighed portion of each was then exposed to a temperature of 350 deg. F. for one and one-half hours, when it was observed that both samples had materially increased in weight, due, of course, to their having combined with oxygen. The sulphur in the state of sulphuric acid was then estimated in both, and found to be almost precisely the same as originally.

The following is a summary of the results:

| | Cannel Coal. | House Coal. |
|---|---|---|
| Increase of weight between 212 deg. and 350 deg. F ..... | 2·00 | 1·90 |
| Sulphur, as sulphuric acid, before heating..... | 0·07 | 0·04 |
| Sulphur, as sulphuric acid, after heating..... | 0·19 | 0·10 |

It will be seen from these experiments that the increase of weight cannot be due to the oxidation of sulphur, as if it were there would have been a corresponding amount of sulphuric acid formed, which was not the case, and it could not arise from the oxidation of compressed or occluded gases, as even if these were not completely expelled by the minute pulverization of the coal and exposure to steam heat, and had combined with oxygen, their products of combustion, being gaseous, would pass off at the high temperature, which would result in a *loss* rather than a *gain* in weight. It is this gain in weight which is the key to the whole question of the *rationale* of the process of spontaneous combustion in coal and other carbonaceous substances. The carbon or carbonaceous ingredients of the coal combine with oxygen, forming *fixed* substances, and so increase in weight by the amount of oxygen with which they have combined. Now, the amount of oxygen which entered into combination in these experiments was approximately 2 lb. to every 100 lb. of coal, and was capable, if utilized for the ordinary combustion of carbon, of giving off heat nearly equal to what is evolved when 1 lb. of coal is burned. These results, moreover, make it clear that whatever part the contained gases take in aiding the action at the commencement, they are not required to carry it on, as their combination to form new products could result only in loss of weight, and not gain.

It has often been stated, and with truth, that chemical analysis throws no light whatever on the liability of a coal to spontaneous combustion, but while this statement is correct for such analyses as are usually made, it by no means follows that a chemical examination of the coal carried out on proper lines might not be useful in determining its qualities in this respect. The analysis required for technical and commercial purposes is one showing the percentage of carbon, hydrogen, oxygen, nitrogen, sulphur, ash, and moisture, but the relative proportions of these are not and never were intended to have any reference to the safety or otherwise of a coal for shipment or storage, and it is only such tests as are made with that special object in view that can ever be of value for that purpose. But while the elementary composition of a coal gives us no information on this point, it is extremely probable that a knowledge of its proximate constituents or compounds would be of great service. These are the decomposition products of the woody matter from which the coal was formed, but, unfortunately, little or nothing is known of them except that they differ widely in different coals, some of them being unstable in their nature and, consequently, liable to chemical changes with production of heat, while others are of a stable character, and, therefore, not prone to such change. The subject affords a wide and interesting field for investigation, both for the scientific and the technical chemist. It is not at all unlikely, however, that experiments on the small scale, such as those described, carried out upon the principal coals intended for shipment, might indicate the degree of their liability to heat and ignite spontaneously. There are also other points worthy of attention, such as the amount of moisture which a coal retains after being air-dried. Many hold as much as ten per cent. retained at 60 deg. F., and expelled at 212 deg. F., and it is reasonable to suppose that water may either take part in bringing about a chemical change or that any portion of it which would be expelled by a moderate heat of say 100 deg. F. to 110 deg. F. would leave the coal to some extent in a spongy or porous condition, which would favor oxidation.

The spontaneous heating of oils in a finely divided state has been made a subject of observation among chemists and others for a very long period, and the conditions under which it takes place are too well known to require any reference. All that is necessary is that the oil should expose a large surface to the air, and if the latter is warm and still, the action commences with great ease and progresses with astonishing rapidity. Numerous and varied experiments have shown that some oils are far more prone to oxidation and heating than others. Among vegetable oils, linseed stands prominent in this respect, and of animal oils, seal shows the greatest tendency, while mineral oils not only show no disposition to heat, but when mixed in comparatively small proportions with heating oils, annul or neutralize the heating proclivities of the latter. Attempts based upon the results of spontaneous combustion experiments have been made to arrange vegetable and animal oils in the order of their liability to heat or to combine with oxygen, but their behavior under experiment is far too fickle to allow of any but a very rough classification, admitting of certain oils being placed at or near the top of the list, others at the foot, and the remainder somewhere intermediate. It has been observed by Mr. R. T. Thomson, however, that those oils which are capable of combining with the largest proportion of iodine are precisely those which have the greatest affinity for, and combine with, the greatest amount of oxygen under favorable conditions; and there can be no doubt of the correctness of this view.

It has been, and still is, the result of painful experience that many of the most destructive conflagrations owe their origin to the affinity of certain oils for oxygen, although there must be some instances in which this has been wrongly assigned as the cause. It is clear that any fire having its origin in a building such as a Turkey red stove, where goods prepared with oil are suspended at a high temperature for a considerable length of time, would in all probability take place in one of three ways:

*First.*—By the elimination of combustible vapor from the oil by the heat of the stove, producing an inflammable atmosphere, which would at once ignite on contact with a spark or flame.

*Second.*—By a spark escaping from a chink or crack in the heating flue of the stove (or brought into the apartment in some other way) coming in contact with the hot and dry goods.

*Third.*—By the extra heat—over and above that of the stove—generated by the oxidation of the oil; this would promote further action, developing more heat, and so the action would proceed, in an accelerating ratio, till the ignition point was reached, immediately before which a large quantity of inflammable vapor would be distilled off from the highly heated portions of the oil surface.

The first of these causes may be dismissed, as the amount of gas or vapor which could possibly be thrown off from the oiled goods would not be sufficient to form an explosive or inflammable mixture with the air, nor such as would ignite by contact of either spark or flame. The second could not and need not be made the subject of experiment, as the effect of direct contact with fire is obvious. It is only the third of these probable causes, therefore, that could form the subject of direct inquiry, and for this reason, as well as because it seemed probable that the majority of disasters arose from this cause, I thought it desirable to institute a few experiments, with the object, not so much of throwing light upon this point, as of determining in what direction investigation might proceed.

In order to ascertain whether olive oil gives off an inflammable vapor such as would ignite on the application of a flame, or spontaneously at the temperature of a Turkey red stove, say 180 deg. F. to 184 deg. F., I prepared some gray cotton yarn by soaking it in a well known brand of olive oil (Gioja), pressing out the excess until only 10 per cent. remained, and heated this in an Abel's flash point apparatus for some hours at 200 deg. F., but no vapor was given off that would flash or ignite on the application of a light at any period of the trial. The same was tried on the "fatty acids" of olive oil, with the same negative results, which makes it certain that both olive oil and the fatty acid recovered from it are safe as far as this point goes. All the materials, both yarn and oil, were carefully weighed before and after in these trials, in order to ascertain whether there was any increase of weight due to oxidation of the oil at the high temperature, but the results were unsatisfactory, the weights fluctuating on account of the hygroscopic character of the cotton fiber, and the difficulty of getting accurate weighings without absorption of moisture from the air, which vitiated the results. Recourse was then had to heating the dry oil to a temperature of 194 deg. F. *alone*, without any fiber, but merely spread in a thin film over the flat bottom of a platinum basin, with the result that in twenty-four hours there was a clear gain in weight of nearly one per cent., which steadily increased until a point was reached, at the end of sixty hours, at which it appeared to remain stationary, probably on account of some decomposition and evolution of vapor, thereby causing a loss in weight which would neutralize the gain in weight by oxidation. The oil was purified beforehand by removing from it the free oleic acid which all olive oils in the market contain more or less. The fatty acids from oil were then tried in the same way, but instead of showing a gain, like the oil itself, they showed a loss nearly to the same extent, but this was, no doubt, due to a chemical change producing some volatile body which passed away, and that this more than counterbalanced the gain in weight by oxidation, which was really going on at the same time. The fatty acids of cotton seed oil behaved in the same way, but those of linseed oil showed a gain of over one per cent. in twenty-four hours. Stearic acid, on the other hand, remained almost constant in weight after exposure for fifty hours.

Now, at first sight it may appear that as the fatty acids of olive, cotton, and other oils lose weight on being kept hot in a close place, the vapor or substance given off being inflammable would give rise to an atmosphere that would "flash" on contact with a spark or flame, and that, therefore, these would be dangerous from that cause, but a little examination will show that this cannot be the case. Suppose an example in which a ton of fatty acids of olive oil was thinly spread over the surface of cotton goods in a stove 60 by 40 by 30 ft. at 182 deg. F., and that the weight of volatile vapor given off in twenty-four hours was one per cent., the conditions would be 5,600 lb., or thereby, of air through which was diffused 22·4 lb. of combustible vapor or gas, which would be equal to 0·4 per cent. Such a mixture would be perfectly safe to carry a naked flame through, as it would neither take fire nor explode. About 2½ per cent. of the vapor would require to be present before a combustible or explosive mixture would be reached. The real danger lies in the accumulation of heat produced by the oxidation (involving increase of weight) of the oil. In the above example approximately one per cent. of oxygen would be taken up by the oily matter in twenty-four hours, which, if combined with carbon by combustion in the ordinary way, would give out heat sufficient to raise the whole air of the stove to a temperature of 273 deg. F.; but then the heat, as it was generated, if not removed, would at once become available for promoting further action, producing more heat, and so on until finally the ignition point was reached. But it must not be forgotten that the heat generated would greatly exceed this, as every successive development of heat by the combination of the oxygen with the elements of the fatty acid would facilitate or accelerate oxidation, resulting in the production of more heat, and so on, till the firing point was reached.—*Jour. Soc. Chem. Industry.*

## THE AMENIDE MUMMIES AT THEBES.

A CORRESPONDENT of the London *Times* has obtained direct information from the highest authentic source about the mummies at Thebes. This is furnished by the following extract from a private letter addressed by M. Grebaut, director-general of the excavations, to his learned predecessor, Professor G. Maspero, of Paris:

"Here is some account of a fortunate discovery. Having found, *in situ*, at Deir-el-Bahari, a royal sarcophagus of a queen, and seeing that the surrounding ground had not been disturbed, I thought it worth while to make further excavations on the spot. At a depth of 15 meters we came upon the door of a rock-cut chamber, in which were piled, one above the other, 180 mummy cases of priests and priestesses of Amen, together with a large number of the usual funerary objects, including some 50 Osirian statuettes. Of these we at once opened ten, finding a papyrus in each. There are a great many enormous wooden sarcophagi, containing mummies in triple mummy cases, all very richly decorated. Among these we have found a priest of Aah-hotep. These sarcophagi are of the time of the twenty-first dynasty. What we have found is, therefore, a 'cache' of the same period as that of the royal mummies discovered in 1881, and made by the same priests of Amen.

"Notwithstanding that the soil has remained untouched for 3,000 years, some of these sarcophagi are broken, and many of the gilded faces of the superincumbent effigies are injured. The way in which they are piled up, their damaged condition, and the general disorder point to a hurried and wholesale removal, as in the case of the royal mummies. We find, for instance, a mummy case inscribed with one name inclosed in a sarcophagus inscribed with another, while probably the inner cases may prove to belong to a mummy with a name differing from both. May we here hope to find some royal mummies for which there was not space in the vault discovered ten years ago? I scarcely dare to hope it.

"At a first glance it would seem as if the high priests had abstained from burying the mummies of their more humble predecessors with those of royalty. Everything must, however, be opened and studied. About midway of the shaft now open may be seen the door of an upper vault; and to judge by certain indications, there is also probably an intermediate vault. Had we, however, only the 180 sarcophagi contemporary with, or anterior to, the twenty-first dynasty, it would be a magnificent haul, the greater number of the sarcophagi being really splendid and in perfect preservation.

"There are also some charming things among the minor objects. The name has been purposely erased, or washed off, from several of the large sarcophagi, and the place left blank, as if the scribe had not had time to fill in that of the new occupant; but we may probably find the names of those later occupants on their inner mummy cases. One of the largest of these sarcophagi is surcharged with the name of the high priest of Amen, Pinotem. As soon as we have cleared the lower vault, I shall attack the upper chamber or chambers."

The correspondent explains that the high priests of Amen, at Thebes, were a line of powerful prelates whose succession must have dated back to the foundation of the great temple under the first kings of the twelfth dynasty—a time supposed to be coeval with the visit of Abraham to Egypt. Toward the close of the twentieth dynasty (*circa* 1100 or 1000 B. C.) they had attained to such a height of political supremacy that the first prophet of Amen not only united in his single person the offices of viceroy of Ethiopia and commander-in-chief of the Egyptian army, but he actually took precedence of the reigning Pharaoh, assumed the titles and ovals of royalty, and founded the twenty-first or Amenide dynasty of priest kings. It was during the pontificate of the first of these royal priests, Her-Hor Se-Amen, that the mummies of a large number of kings and queens of the seventeenth, eighteenth, and nineteeth dynasties were removed, for greater safety, from their sepulchers in the valley of the tombs of the kings to places where they could be more adequately protected from the depredations of the gangs of tomb breakers which at that time infested the burial places of Thebes.

These burial places were very numerous, comprising the two valleys of the tombs of the kings, the valley of the tombs of the queens, the necropolis of the priestesses of Amen, and the great general necropolis, which also included the burial places of the kings of the eleventh dynasty. Now, although the necropolis of the priestesses of Amen was well known, no necropolis of the priests had yet been found; and it therefore seemed reasonable to suppose that they were buried within the temple precincts. Whether this was or was not the case, it would now appear that the high priests of the twenty-first dynasty became as much alarmed for the sanctity of their own sepulchers as for the safety of the royal mummies, and that they removed and concealed the mummies of these 180 priests of Amen as expeditiously and successfully as they concealed the remains of the heroic Pharaohs of the four preceding dynasties. There is, however, no ground for concluding that the evident haste with which the transfer was conducted points to a time of national peril. The period of the twenty-first dynasty was one of ignoble decadence and obscure peace; but the tomb robbers were ever on the alert, and it is obvious that, unless a wholesale removal of this kind was accomplished under cover of night and with extreme rapidity, no precautions would avail. The well-founded hypothesis of Professor Maspero, which attributed the concealment of the royal mummies to this standing danger of desecration, accounts therefore with equal probability for the condition of the mummy cases just discovered.

As regards the Osirian statuettes mentioned by M. Grebaut, a large number of similar *figurines* carved in wood may be seen by the visitor to the Upper Egyptian rooms at the British Museum. These statuettes were made hollow, in order to contain a roll of papyrus, but the documents thus preserved almost invariably consist of extracts from "The Book of the Dead," and although in the present case we may expect to find such extracts varied with decrees of Amen and other religious formulæ peculiar to the members of the great Sacerdotal College of Thebes, it does not seem very likely that they will comprise documents calculated to

throw much light upon the history of Egypt. Too much reliance must not, therefore, be placed on the prophetic utterances of those who anticipate large historic results from the bowels of this multitude of Osirian statuettes.

The letter concludes with a summary account of various other interesting discoveries made by M. Grebaut concurrently with his great "find" of Amenide mummies. On the south side of the unique and beautiful temple erected at Deir-el-Bahari by the renowned Queen Hatasu (eighteenth dynasty), part of which was dedicated to Amen of Thebes, and part to Hathor of Punt, M. Grebaut has found an undisturbed tomb of a priestess of Hathor, of the very early period of the eleventh dynasty, thus indicating the probable existence of a yet earlier temple to Hathor on this same spot. It is open to conjecture that that earlier temple might have been founded by King Sankhara, of the eleventh dynasty, who, according to a celebrated rock-cut inscription in the valley of Hammamat, dispatched the first naval expedition to that part of the Somali coast known to the Egyptians as the land of Punt. The name of this newly exhumed priestess was Ament, signifying the region of the Western Shades—in other words, the land beyond the grave.

The door of her sepulcher was unopened, and at the further end of the little funerary chamber stood an enormous limestone sarcophagus, without inscription or decoration. The lid being removed, it was found to contain a broken mummy case, with inscriptions both carved and painted, and inside the mummy case, covered with a number of pieces of neatly folded linen, lay the mummy of the priestess. These pieces of linen bear the makers' marks, and are inscribed with the date of a certain "year 24," but of whose reign it is impossible to say, no royal name being entered. The mummy is that of a large woman, well bandaged. Beside her lay four mirrors, three of silver and one of enamel. In front of the sarcophagus, at the right-hand corner, stood a wooden coffer containing the skin and bones of two sacrificial oxen, several more pieces of folded linen, some little bundles of rags, and three very delicately woven nets, which M. Grebaut believes to have been designed for carrying perfume bottles. So few intact sepulchers of the remote and obscure eleventh dynasty have been found that this discovery, though less startling than the great find of priestly mummies, is of extreme archæological rarity and interest.

## THE ITALIAN NATIONAL EXHIBITION AT PALERMO.

THE site of the exhibition to be held in Palermo next winter is the gardens of the Principe di Radali, adjoining the well known Giardino Inglese, which will probably also be annexed. A fine set of buildings occupying an area of 110,000 square meters is now in course of erection, from the designs of Signor Basile, the architect. A general view of them is given above. The principal galleries will be those devoted to railway materials, machinery in motion, the textile industries, liberal arts, and Pompeian saloons. An important feature will be the international section for engines, machines, and labor saving appliances for small industries, meant to be easily fixed and used with safety in private dwellings and workshops, the demand for which has greatly increased of late, owing to the development of co-operative societies among the peasants and artisans. Committees have been formed in the principal cities of Europe. The King of Italy is patron of the exhibition, and has promised to open it in person, on the 1st of November. The government are using all their influence to make this, the first national exhibition held in the south of Italy, a success.—*Daily Graphic.*

## ONION CULTURE FOR PICKLING.

THIS is the most important crop grown for pickling purposes. Messrs. King & Son (Broom, near Biggleswade) grew 130 acres of onions this year (1890), which will average from 10 to 12 tons per acre, it being a very productive season. Light, friable soils with open subsoils are best suited to their growth, and the greatest care has to be taken in preparing the seed beds. The previous treatment of land for growing this crop is by no means confined to the few months immediately preceding the sowing, for it requires to be got thoroughly into condition, both as regards manuring and cleanliness. Certain conditions are decidedly unfavorable to the growth of onions. Land which has been cropped with common field beans rarely produces good onions, for the latter are then liable to "gloat" or puff, in which case they are useless for pickling, as the bulb is too soft. Besides this, onions so grown are much more liable to attacks of the onion grub, as this insect appears to harbor in the straw, or haulm, during some period of its existence, though it has not been actually traced. It not only appears more often on land on which beans have been grown, but when bean straw is used as litter from which dung is made, and the dung is applied for onions, a serious attack is almost certain to ensue. Therefore the cropping has to be arranged so that onions do not follow beans, either directly or after some years, and most onion growers refrain altogether from cultivating beans.

Although heavy dressings of rotten dung are often applied a few months before onion seed is sown, it is preferred to put on a considerable quantity in the preceding years, and thereby to get it thoroughly incorporated with the soil, so that its rankness may be dissipated through the medium of other crops.

Last spring I saw Messrs. King getting a piece of land on their new farm into condition for onions, but the onions will not be sown for at least another year or two. The land was in wheat stubble which had been autumn cultivated and cleaned. It had already received 100 bushels of soot per acre, 25 tons per acre of good London dung were at the time being applied, and after this there would be a dressing of 7 cwt. of dissolved bones. All these were being put on to produce a crop of swedes which would be fed off by big wether sheep, receiving as much cake as they could consume. A crop of peas will be sown in the following spring. If, after the peas, the land seems to be in favorable condition for onions the latter will be sown, but the land will even then receive forty or more tons of dung per acre.

In a well known book on gardening, from which quotations are frequently made, it is stated that a poor soil is necessary for producing the small, firm bulbs required for pickling. This is decidedly wrong, for the land should be made exceedingly rich, and the size of the onion controlled by thick seeding. The manurial dressing previously mentioned, as followed by Mr. Cooper, is by no means excessive, and occasionally the application of dung may amount to sixty tons per acre. This is, of course, very expensive, as London dung, fifty miles out, costs 5s. 9d. per ton at the station, to which has to be added the cost of carting and applying to the land.

In connection with London dung, it is worth noting that onions to which sawdust dung is applied are much more liable to attacks of wire worm than are those for which straw dung is used. Where the presence of wire worm is suspected, it is usual to grow a crop of mustard, and to dress the land with gas lime before sowing the onion seed. This is generally found sufficient to check the pest. If the land is in such good heart, from previous manuring, that dung is not considered necessary, 100 bushels of soot are almost invariably sown during winter, while the land lies in the furrow.

Freedom from weeds is such an important matter that, where market garden farming is practiced, the stubbles are never used as sheep runs, but the land is broadshared or skimmed immediately after harvest to prevent seeding, or the land is at once broken up to be made into a seed bed for immediate sowing. The cost of cleaning onions is so great that, even under favorable circumstances, it rarely amounts to less than £5 per acre, from £4 to £5 10s. being the usual range of prices. Mr. King once pointed out to me a field which he said cost £20 for weeding the first time he grew onions on it, but which, owing to thorough cleaning and the prevention of weeds from seeding, cost only 30s. an acre the last time he took onions upon it.

In ordinary cases the land is broken up as soon as the previous crop is out of the way, and any filth is at once cleared off. It is allowed to lie through winter, and dung is carted on when there is sufficient frost, but the land is not disturbed until a favorable opportunity occurs early in the new year. It is then worked most thoroughly, and brought down to a fine but solid tilth. An onion tilth cannot be too fine, as the seed germinates more thoroughly and more evenly the finer the soil. As it will not germinate if sown too deeply, a rough surface would result in some portion of the seed being over-buried, if the rest were put in at a proper depth. Nevertheless, after finely reducing the soil it must be solidified, but not worked when wet, or it will become packed, which is injurious.

The seed is generally sown broadcast for growing "picklers," as the onions are better distributed about the ground, and each plant gets a fairer share of the space than when placed in drill rows. After seeding it is harrowed in with light harrows or raked in with iron hand rakes, and, if occasion demands it, rolled as well. The subsequent workings consist of hand hoeings and weedings. The quantity of seed sown is generally from 60 lb. to 80 lb. per acre, but if its germinating power is low, as much as 1½ cwt. has been used. The appearance of the field when the onions are about four inches high is not unlike that of newly laid down grass land when viewed at a short distance, so thick do the young plants stand. There is no thinning, all the plants being allowed to mature. The seed varies in price very much, the usual quotation being from 1s. 6d. to 10s., though it has been as much as 20s. per lb. The cost of the seed is thus a very serious item, and the growth of seed is a most important part of the onion grower's business, which must be briefly noticed.

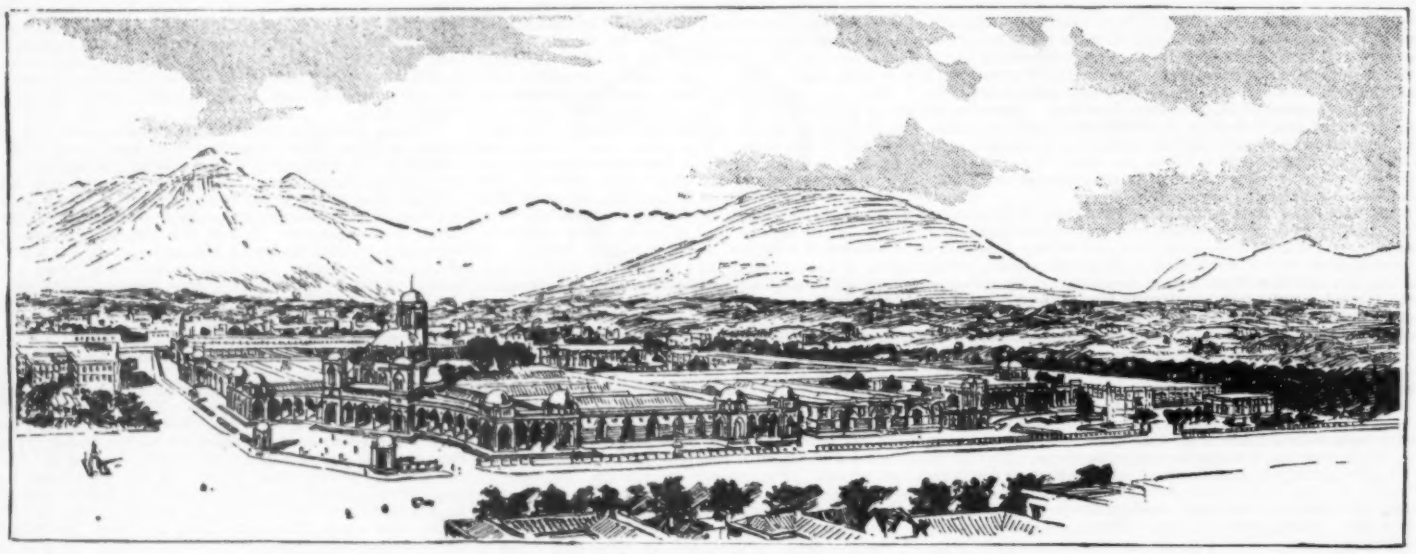
The usual method is to grow the seed from bulbs placed in rows about two feet apart, though a considerable quantity is grown in rows much farther apart, when used for providing shelter for cucumbers. Strong land grows the best seed, although light, friable soils are most suitable for growing bulbs. Well shaped onions are selected, and are transplanted in February in rows, about three tons per acre being required for planting a full crop. These, as a rule, will come to seed fit for gathering in September. The whole crop does not ripen at once, but as the seed heads are fit they are cut and collected, and placed on cloths to dry.

The method of drying the heads so that the seeds will thrash out freely is somewhat tedious. The heads are placed on cloths resting on straw and spread out during the day, but before night or rain they are raked up into the middle of the cloth. Above the cloths hurdles are set up like an inverted V, and the ends of the cloths are turned up over them. The straw which thereby becomes exposed is gathered up, and placed on the top of the ridge formed by the hurdles. When the heads are dry enough, they are thrashed by means of the flail. In very windy weather, loss often arises through the seed being blown off the cloth, where, if any seed falls out of the heads, it is collected.

As onion bulbs are worth from £3 to £10 per ton, and sometimes even more, seed growing is very expensive. Unfortunately the crop is very subject to destruction by mildew (*Peronospora Schleideniana*). This fungoid disease, which also attacks the young onions, generally appears in cold wet weather in July. The young plants are not, as a rule, destroyed, though in bad cases they make no further growth; a very severe attack on the pipes or stems which carry the seed heads may result in the loss of the whole of the seed. In the years 1888 and 1889, the seed crops were most seriously injured, nine-tenths of some being absolutely killed; while very few crops suffered loss to the extent of less than one-third. Seed was therefore dear, and there was a large demand for that of foreign growth, which, though often very good, cannot be relied upon. The Russian seed is commonly to all appearances perfect, but it is not infrequently useless for pickling purposes, because the bulbs grown from it split like chestnuts, having some resemblance to shallots, which are objected to in the trade merely on account of their shape. I saw a field of 14 acres, which—regarded casually—appeared to be perfect; but when the onions were skinned for pickling they were found, from the cause mentioned, to be useless, and the owner calculated that he had lost £1,000. This was not his first experience of serious loss from this cause. The best seed for the purpose in view is the English grown Spanish onion as a main crop, though the silver skin is occasionally cultivated for producing specially early bulbs, in order that a start may be made with the brining in good time.

To return to the pickle crop, which was described as being sown. The hand weeding commences as soon as the onions are well up, this work being done chiefly by women and children, who go down upon their hands and knees and carefully pick out or cut out every weed. No top dressings are applied, as artificial manures are not popular; nitrate of soda and other nitrogenous manures are found to cause an excessive growth of neck and soft bulb, producing what are called "romps," that is, onions of rampant growth, which are altogether unsuitable for pickling purposes. Farmyard manure is the fertilizer most preferred, as it retains the moisture in dry seasons and keeps the soil open in wet ones. Soot is the market gardener's favorite concentrated manure.

The onions for pickling are hoed up with either the hand hoe or the horse hoe; when they are loosened they are collected by hand into rows. It is best to take them away and peel them at once, but this is not always practicable.



THE ITALIAN NATIONAL EXHIBITION AT PALERMO.

Onion bulbs are liable to two diseases—one is known as "mouldy nose," and attacks the nose or root end either before or after pulling, but it is generally caused by excessive wet; when once thus attacked the bulbs are spoiled for pickling. The other disease, known as "stale rot," attacks the crown after pulling, and while the bulbs are stored, so that it is not discovered until they are handled.

The operations of peeling and brining are not generally understood, but as they enter into the pickle grower's business they may be briefly described.

The onions are brought to sheds, and there sifted with the object of removing the bulbs which are too big for pickling, and also to clean them to some extent. The suitable ones are then handed over to women or children, whose duty it is to cut off the tops and bottoms, and to peel off the outer skins until the bulbs are free from deeply colored portions. These, after being inspected, are thrown into a large tub of fresh water and washed, after which they are placed on sieves and separated into different sizes. In all, five sizes are made up; the smallest are the most valuable and are called "pimps," while the others grade as firsts, seconds, thirds, and fourths, the last named, rather more than an inch in diameter, being the largest which are received in the trade. The onions are next placed in water and well washed, after which they are put into separate barrels, and when the barrels will hold no more a strong brine is poured into them, and they are coopered up. The work, so far as the briner is concerned, is now finished, except that from time to time it is necessary to fill the barrels with brine, as loss arises from evaporation, and also from shrinkage of the onion itself. The process of brining is necessary to destroy what is known as the "vegetable" in the onion, that is, the green coloring, which the brine does in course of time. Some manufacturers will not use onions until they have been in brine at least a year. It is very largely due to the circumstance that they are not brined that home-made pickles are not so bright and clear as those made by large firms. The quality of the water is an important factor, for if it is too hard and the onions are left in it for a day or two, they become black.

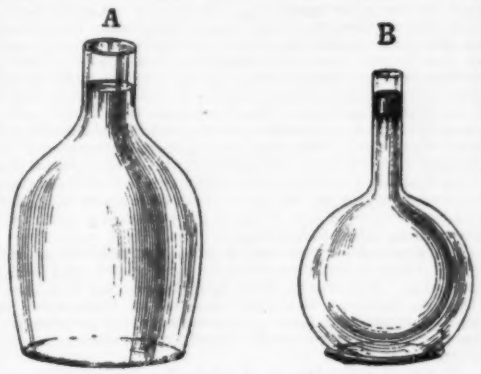
As showing what a quantity may be grown on one farm, it may be mentioned that in 1889 Messrs. King brined 4,000 casks, which were the produce of about 90 acres; this year they grew 130 acres, and the yield is much greater per acre. In addition to this, they will brine something like 1,000 barrels of cauliflowers, and about 400 or 500 barrels of cucumbers and gherkins, all the produce of their farms. Others interested in pickling and brining grow their own material, besides occasionally purchasing from smaller growers. During the past few years considerable quantities of pickling onions have been imported from Russia and other countries where labor is cheap. Though it is to the interest of the English farmer not to allow others to step in, the grave difficulty of labor is one which market gardeners must look forward to with even greater anxiety than ordinary farmers, as so much of their work has necessarily to be done by hand. Their greatest safeguard against foreign competition appears to be in the employment of women and children. Messrs. King for some months during the pickling season employ as many as 1,000 hands, the greater number of whom come from neighboring towns and villages; but men are required for all the heavier kinds of work.—W. J. MALDEN, *in Journal of Royal Agricultural Society.*

## OTTO OF ROSES.

EARLY in the 17th century, according to Persian authors, otto of rose (from the Arabic *itr*, perfume) was discovered by a certain princess, who observed oily drops floating upon the surface of a fountain or stream of rose water, provided by the munificence of her husband, the great mogul, and ordered that they should be collected and preserved. The cultivation of roses for the preparation of this fragrant essential oil seems to have originated in Persia, whence it spread southward and westward into Arabia, and the states of Barbary. From Tunis, according to tradition, the art of distilling otto of rose was carried to Bulgaria, and at any rate the *Rosa damascena*, now cultivated in Turkey, was formerly reared in Tunis, though now it is almost extinct there. It further appears from such records of the cultivation as are to be come at, that for a considerable period it was restricted to the immediate neighborhood of Kezanlik, only extending to the neighboring villages and districts within the last half century, during which time the output of otto from Kezanlik and the adjacent region has increased about tenfold. From a booklet on the rose industry of Bulgaria, by M. Christo Christoff, of Kezanlik, translated by C. H. Piesse, consul-general of Monaco, and published by Messrs. Piesse & Lubin, we have gleaned the following interesting particulars of the rearing of roses and distillation of otto in Roumelia. Of course, we know the essential oil of rose is produced largely in India, in the south of France, in Tunis, and in Persia, but from these countries none finds its way into the London market. The chief localities in which the rose is cultivated in Turkey for the production of otto are those surrounding Kezanlik, a large town situated on the southern slopes of the Balkan, and some seventy miles north of Adrianople. The rose is also cultivated on the large scale in the valley of the Tounja generally, and in the cantons of Karlova, Novo-selo, Brezovo, Pechtera, etc. Kopriveh-titza on the west, and Ivarditza on the east, form the limits of the industry, which thus extend along a tract of country some eighty miles long, between the Balkans proper on the north and a spur of that range called Snedna Gora on the south, at least the best otto is produced within this area. The kind of *Rosa* cultivated is chiefly *R. damascena*, though to a less extent *R. alba* is also reared. The latter species yields an oil of very inferior quality, but richer in staeroptene. The peculiarities of the Bulgarian district, which constitute its supremacy over other places where the cultivation has been attempted, are chiefly four, viz., (1) its sheltered position south of the Balkans; (2) its pervious sloping soil, from which moisture rapidly drains off; (3) the abundance of firewood; and (4) the plentiful character of the water supply. The last two factors, of course, are of more significance in distillation than in cultivation. The temperature varies between 4 deg. F. in winter and 104 deg. F. in summer, and often changes very suddenly. The mean temperature is about that of France. The plantation of a rose field takes place in October or November, the method of raising new plants being a kind of "layering." The branches of old trees are laid down horizontally side by side, four or five together in

trenches, and lightly covered with earth and manure. In the following spring the young shoots appear, in the second year a few flowers are yielded, and in the fifth year the bushes attain their maximum production, though with care they continue to furnish a crop beyond their twentieth year.

The work of the cultivators includes weeding and plowing three or four times yearly, pruning from withered branches when necessary (in March generally) and protecting the roots during winter, by banking




them up with earth. As a rule artificial watering is not practiced, as it seems to render the plants more sensitive. The harvest begins in the middle of May and ends in the middle of June, and the more slowly the flowers appear, the easier the crop is to collect and distill. The gatherers are out in the fields at dawn, and every flower that has begun to blow is gathered. A million roses, weighing nearly exactly a ton, are produced by four-fifths of an acre of plantation, and yield at most about 12 ounces avoirdupois of otto (equals

about 0·3 per mille). Large proprietors have fixed stills built under covered sheds. The peasants' stills are of the same kind, but are frequently portable. They consist essentially of a large copper alembic of a special shape, shown in the appended illustration (from Mr. Christoff's brochure). The only explanatory comment necessary is that the condenser is a straight tin tube (about four feet long), and not a worm. The hot water flows out from the barrel by way of an internal tube open at the top (near the surface of the water) and

passing through the bottom of the barrel. Each apparatus takes a charge of about 22 pounds of flowers and 16 gallons of water, and in about an hour and a half two flasks of the shape shown in Fig. A, with a capacity of 5 liters (8¾ pints) each, will have been filled with rose water.

From this the otto is extracted by redistillation of about nine gallons at a time, the product (a little over one gallon) being collected in flasks represented in Fig. B. The water in the still is used for the distillation of more roses. As the contents of the long-necked flask cool, the otto separates at the surface and is collected in special "dippers" or ladles shaped like conical extinguishers with long tin handles, and having at the apex a minute hole through which the water scooped up with the otto is allowed to drop back into the flask. The collecting flasks or receivers for the pure otto hold from about a half pound to two and one-fifth pounds. Two are represented in C and D. Since 1871, only three harvests have been below the average indicated by a produce of 4,000 to 4,400 lb. (1872, 3,300; 1877 and 1878, 3,960), while three have been good, and two (1871 and 1889) very good, the yield being 6,600 pounds. Practically all the oil is centralized in six Bulgarian and two German houses in Kezanlik, whence it is exported to Europe in vessels generally of the kind figured at E.—*Monthly Magazine.*

## HOW TO MEASURE THE INVISIBLE.*

By HENRY M. PARKHURST.

WHEN Comte's Positive Philosophy was published, some forty years ago, Kirchhoff had not made the discovery which lies at the foundation of all spectroscopic analysis. It seemed then that there could be no question of the correctness of his assertion that the chemistry of the stars would be forever beyond the reach of human investigation. What could be more certainly impossible than that men of science, separated from the stars by millions of millions of miles of space, void with the exception of a possible ether, so ethereal as not to perceptibly interfere with the motion of the rarest comets, could ascertain what substances exist, and their chemical nature, in those inconceivably distant orbs? His reasoning was good; but his argument contained a flaw in assuming as a self-evident fact that which was not a fact. The sense of sight alone can give us information with regard to the stars. No sound can cross the depths of space; still less can our other senses aid us; for they require proximity if not actual contact as the basis of their indications. Comte argued that all that we could learn of the stars must be learned through the instrumentality of the sense of sight; and he assumed that it was absolutely impossible for us by the sense of sight to distinguish between the different chemical elements in the stars. Yet the discovery of the principle of the spectroscope has made this seeming impossibility possible. Comte's system of positive philosophy was founded upon the assumption that there were some things that men positively could not know; that it was useless to look for it or to hope for it; and this was one of them. Let me read to you his exact language:

"Of all objects, the planets are those which appear to us under the least varied aspect. We see how we may determine their forms, their distances, their bulk, and their motions, but we can never know anything of their chemical or mineralogical structure; and, much less, that of organized beings living on their surface."

Although the word "planets" is used in the translation of this sentence, it is of the stars that he is speaking, and the argument applies equally to the planets and the fixed stars. The fact that to-day what he pronounced forever impossible, and there was no one to tell him nay, has already been attained, should be a lesson to us never to be positive of the impossibility of attaining any sort of knowledge. Whatever knowledge man has sufficient conception of to imagine a theory with regard to, there is, so far as we know, a possibility of his reaching, in some way and at some time. As with regard to the mathematical computation that no steamship could ever cross the Atlantic, because the coal would not furnish sufficient power for its own transportation, it seems as if the very announcement of an impossibility served but as a prelude to emphasize the marvelous achievement.

Before the invention of the telescope an object upon the moon's surface fifty miles in diameter could not be seen; and it seemed impossible that men should ever know anything about lesser objects. By the argument of Comte, man was forever debarred from knowing about such objects. Leaving out of view the possibility of optical magnification, the sense of sight having already reached the limit of its power, there was no basis left for further discoveries; and among absolute impossibilities, quality was no more to be rejected as unattainable than quantity. The invention of the telescope has introduced a new element before unthought of; and it has taught us the first mode of measuring the invisible; which is, first to make it visible, by magnifying it optically. The thousands of minute craters upon the moon's surface can now be measured; whereas before the invention of the telescope their existence could not be suspected. We have not yet learned what limitation attends this mode of magnification. Each new large telescope, making visible and measurable that which was before invisible, leads to the construction of another larger telescope; and the end is not yet. The great refractor of the National Observatory, when I was there, had an aperture of less than ten inches. Then came the Harvard refractor of fifteen inches. The Chicago telescope of eighteen inches succeeded. Others still larger followed, until the new refractor of twenty-six inches aperture replaced the old one at Washington. At last has come the Lick telescope of thirty-six inches, eclipsing all predecessors. And even now the Clarks are engaged in the construction of a still larger telescope, which is expected to excel even the Lick telescope.

Not only may we have larger telescopes, but new discoveries in the manufacture of the lenses may so improve their definition, by getting rid of the irrationality of the spectra, as to still further increase their magnifying power. Such improvements cannot add much in the observation of excessively faint objects, but may add materially in observations where definition is required rather than light.

It will take many years to double the power of our largest telescopes, if it can ever be done; and it is natural to suppose that the power of measurement must await the improvement of the telescope. We may measure the invisible by first making it visible; but how can we measure it if we cannot make it visible? The sight is our only sense which reaches beyond our own little planet. If we cannot take cognizance of a distant object by our vision, how can we know that it exists?

* A lecture delivered before the astronomical department of the Brooklyn Institute, October 13, 1890, and illustrated with lantern views and diagrams.—*From the Sidereal Messenger.*

One answer to this question it is not difficult to find. In an eclipse of the sun, we cannot see the moon; but we know that it exists from its intercepting the rays of the sun. Even if we never saw the moon at any other time, we should know in a solar eclipse that it existed. Or if that is considered too metaphysical, I will pass at once to another illustration.

The irregularities in the proper motion of Procyon have been found to indicate that it is accompanied by a body invisible to us, and yet of sufficient mass perceptibly to affect its motion. Procyon and this invisible body revolve around a common center of gravity. We know that this dark body exists, and we know approximately its direction from Procyon and the period of its revolution. But these facts do not give us any means of measurement. We cannot learn from these facts, so far as I can see, anything whatever with regard to the distance between the bodies, or their relative size, or absolute size, or anything which can properly be called a measurement. In like manner and still earlier, Sirius was found to have an irregular proper motion, inducing the belief that it was attended by an invisible companion. The subsequent discovery of the companion of Sirius, very faint but of considerable size, while it confirms the hypothesis of the cause of the irregularities in the motion of Procyon, makes it no longer possible to cite Sirius as an illustration of a bright star attended by a known invisible companion.

It has long been thought not improbable that the variable star Algol is accompanied by a dark body which, at each revolution, comes between us and the principal star, and cuts off a portion of its light, causing its brightness to fall from the second to the fourth magnitude. Here all that we see, and all that any telescope can show us, is the diminution of the light. If we knew that the dark body passed directly and centrally between us and the bright star, this would give us an approximation to the relative sizes of the two bodies; but even upon that hypothesis we could not know their actual size or distance. It is manifest that if the plane of the orbit should be, as it would be most likely to be, inclined to the line of sight (the line joining Algol and the earth), the dark body might not pass entirely across the disk of the other; so that it is impossible to say how much larger the dark body is. In the existing state of our knowledge it seems probable that the dark body is the smaller of the two. It is difficult to understand how one body can be glowing with heat, while another body of equal or larger size, under very similar conditions, is so cooled down as to cease to be luminous. To reduce this difficulty as much as possible, it is assumed that the dark body passes nearly centrally over the other at each revolution, and that its size is only enough to account for the amount of light obstructed. This does not remove the difficulty, but it reduces it. In any event there is so much hypothesis mixed with our known facts that our results cannot properly be called results of measurement, and such results are not measures of the invisible.

Yet we are not left to mere hypothesis in this case. The telescope enables us to measure the invisible by first making it visible; the spectroscope enables us to measure the invisible without making it visible; and this is the matter which I wish to-night specially to explain.

Let me first remark that the spectroscope not only upsets our preconceived notions of the possibilities of things, but reverses the order of its revelations. When an object is presented to our view, we first form some idea of its form, its distance and its size; and the investigation of its nature, and the nature of the substances of which it is composed, comes afterward. But in these mysterious revelations of the spectroscope in the stellar universe, it first revealed to us the nature of the substances of which the stars were composed; then whether gaseous or solid, whether of a high or low temperature; and its last achievement is the measurement of distances and of masses.

The principal star in the constellation Capricornus is a double star known before the invention of the telescope. The apparent distance of the two stars is about 6'. Soon after the application of the telescope to astronomical research it was found that there were much closer double stars, so close as not to be distinguishable by the naked eye. Every advance in the improvement of the telescope has brought to our knowledge still closer double stars, the distance between them being so magnified as to become visible and measurable. But the spectroscope has revealed to us a double star so close that no telescope will show the distance between the two stars, although each one of the two stars is bright enough to be visible to the naked eye; and I shall endeavor to explain to you how it is capable theoretically of revealing to us the duplicity of stars so optically close that no possible telescope of the future could ever separate them.

In order to make this intelligible, it will be necessary for me to explain what the spectroscope is, and how it gives us information. As preliminary to that, and to make its indications certain, on their face, I must speak of the nature of light, and especially of color. I shall speak of these points with sole reference to explaining and demonstrating this latest achievement of the spectroscope.

I will not go back in the history of the spectroscope to the time of the flood, when the colors of the rainbow first attracted attention; but will begin with the time of Newton, who in 1664 studied those same colors, produced by refracting the sun's rays through a glass prism. He found the solar rays to consist of rays of different degrees of refrangibility. When the aperture through which the sunlight was received upon the prism was a circular hole in the shutter, each kind of light formed a circle in a different place, according to its refrangibility, the different circles lapping over each other and mingling their colors. By changing the form of the aperture to a slit, he found that the colors became much more pure. Carrying out the same plan to greater perfection, Wollaston observed in 1802 some of the principal dark lines in the spectrum, which he considered as the boundary lines between the different pure colors. These lines were carefully observed and mapped by Fraunhofer in 1814. Were the rays of light of all degrees of refrangibility between certain limits, there would be no dark lines. In the continuous spectrum of an incandescent non-volatile substance, such as carbon under ordinary conditions, there are no dark lines. The existence of these dark lines in the sunlight shows that there are certain degrees of refrangibility which do not exist in the sunlight as it comes to us. It was the discovery by Kirchhoff, in 1859, of the cause of this, of the way in which these kinds of rays in the original light from the incandescent body of the sun are weeded out of the continuous spectrum by glowing gases in the sun's atmosphere, which was the first step in the science of spectroscopy.

When common salt is put into the flame of a Bunsen burner, instead of its light becoming diffused in a continuous spectrum, it is wholly confined to two narrow lines, close together. Upon comparing the position of these two lines with the lines of the solar spectrum, it had been found that they exactly, or at least very nearly, corresponded with Fraunhofer's two D lines. Kirchhoff traced the identity of the lines, and showed it demonstrated the existence of the vapor of sodium in the sun's atmosphere. It is remarkable how nearly the discovery had been made many years before. Even before the discovery of the lines in the solar spectrum, Euler, reasoning from the nature of wave motion, had enunciated the principle that "Every substance absorbs light of such a wave length as coincides with the vibrations of its smallest particles."

Again, in 1853, Angstrom enunciated the principle that "A luminous gas absorbs rays of the same refrangibility as those which it emits." But although these principles were enunciated, there does not appear to have been any attempt to verify them by experiment, or any clear conception of the resulting consequences, until the observations of Kirchhoff in 1859. From direct comparison of the two bright sodium lines with the two dark D lines of the solar spectrum, and from observation of the effect of a sodium flame to produce the same two dark lines when a bright light shone through it, Kirchhoff was convinced of the existence of the vapor of sodium in the sun's atmosphere, and at once proceeded to investigate what other chemical elements could be found to exist in the sun's atmosphere by the appearance of their lines in the solar spectrum. His most remarkable result was the discovery that more than sixty dark lines in the solar spectrum exactly coincide with as many of the bright lines produced by the vapor of iron; demonstrating the existence of iron in the form of vapor in the sun's atmosphere. And later there have been found to be no less than 400 iron lines in the solar spectrum. Various other chemical elements are also identified. But for my present purpose it is enough to have made it apparent that the cause of the dark lines in the spectrum of the sun and of the stars is known, and that we can safely rely upon the conclusions which follow from the phenomena which we observe in relation to them.

The general laws of optics are most readily understood when light is conceived of as an emanation of particles. But investigation has shown that this is not its true nature. It really consists of vibrations, or waves, or modulations; and it is necessary to take that view of it in order to understand the phenomena I am about to explain.

Waves of light consist of alternate condensation and rarefaction of the ether. It is stated in the books that the different kinds of light move with the same velocity, but that the wave lengths, or the distances between the points of greatest condensation, vary. The shorter the wave length, the more is the ray affected by a refracting medium. This is a fundamental principle; and I think a few suggestions, founded upon facts within our own observation, will be sufficient to establish the principle that the extreme red and the extreme violet rays of light move with the same velocity.

For convenience I will assume that if there is any difference, the violet rays move more rapidly than the red; since with equal wave lengths the extreme violet rays would move nearly twice as fast as the extreme red. In a total eclipse of the sun, when the sun emerges from behind the moon, all the rays start from the moon's edge toward the earth at the same instant. If the violet rays moved most rapidly, they would reach the earth first, and the first glimpse of the sun would be an intensely violet streak of light. For the same reason, the last glimpse of the sun before the totality would be an intensely red streak of light. No such difference has been noted. But as the difference is only for the gain of the violet rays in the distance from the moon to the earth, which the light traverses in little over a second, the time during which the effect would be visible would be but a fraction of a second.

Let us take then an eclipse at a greater distance. When the shadow of the first of Jupiter's satellites falls upon its disk, it takes forty minutes for the light to reach us. If the violet light moved twice as rapdly as the red, there would be red rays still reaching us for twenty minutes after the violet rays had been cut off. During those twenty minutes the shadow would have moved over one-seventh of Jupiter's diameter. There would therefore be a fringe of red light next the shadow and following it, extending across one-seventh of Jupiter's diameter, gradually approaching whiteness. For the same reason there would be a fringe of violet light next the shadow and preceding it for an equal distance. The fact that no color is observed proves that if there is any difference in the velocity of the light of the two colors it is exceedingly small. We have still another test, more delicate still, although not resting upon so sure a foundation. If the diminution of the light of Algol arises from the interposition of a dark body, as seems probable, we have the distance between Algol and the earth, in which the different colors pursue their race; so that if during that distance either gained many minutes upon the other, it would become evident by giving to Algol a corresponding tinge during the latter part of the period of its minimum. In some variable stars a red light is seen; but to be produced by this cause it must be supplemented by an equally observable violet light; which has never been seen, although carefully looked for. We may consider it demonstrated, therefore, that light of all colors moves with the same velocity.

The analogy between waves of sound and waves of light gives another illustration. If the same principle of more rapid motion for short wave lengths were applied to music, the high notes would reach us sooner than the low notes; so that in listening to strains of music in the distance, the high notes would reach us a quaver or semi-quaver too soon. Carrying it still further, at the distance of a mile the first line of Duke Street, "Lord, when Thou didst ascend on high," going up the octave, would have its notes all reach us together; and upon going another mile all would be reversed, the high notes coming first, apparently descending the scale as in the tune of Antioch.

The mode of measuring the wave length of the different colors, and the effect of wave length upon refrangibility, I cannot well explain without diagrams, and will defer for the present. But there is one other preliminary suggestion I can make now.

The refrangibility of light depends upon its wave length. When a wave strikes a refracting surface, what determines the degree of the refraction? That wave passes along in its refracted course without waiting for the next wave. Each wave is refracted independently. My explanation is this: The force of light is divided between the different waves emitted within a given time. There being twice as many violet rays, each has but one-half the force of the red light, it is therefore more retarded by the denser medium, and for that reason bent farther from its course. The fact that red light has sufficient force to penetrate the mists of the morning and evening sky, when the violet rays are stopped, indicates the probability of the correctness of this explanation.

The retardation of waves of light by a refracting medium can be illustrated effectively, I will not undertake to say with how much accuracy, by comparing them with a person attempting to cross Brooklyn bridge at a time when it is so crowded that he is compelled to forget good manners and push his way by main force. The more dense the crowd, the slower his rate of progress. The stronger he is, the faster he can get along. The moment the way is clear he resumes a pace as rapid as before entering upon the bridge. So the waves of light, however much they are retarded in passing through a dense medium, do not lose their progressive force, as if they had been detained by friction, but, as shown by their outward refraction at the second surface of a lens, they pass onward with unabated vigor and speed.

It is an important consideration that the effect of a refracting medium does not depend upon the absolute wave length, but upon the relative wave length. We have an illustration of this with reference to the waves of sound in the whistle of a passing locomotive. As it approaches us the pitch is a little higher than it would be if stationary, and the moment it has passed, the sound becomes perceptibly lower while it is receding. To return to the bridge illustration, if the crowd is moving in the same direction with ourselves, we can get along much faster than if it is moving in the opposite direction. The fact that we are moving toward a star does not increase the refrangibility of its waves by shortening their absolute wave length or by weakening their force. But it diminishes their relative wave-length, and it diminishes their power of progressing through the obstacle of a dense medium; and thus it diminishes their velocity, and this increases the refrangibility.

If we were to approach the sun with the speed of light, 200,000 miles per second, carrying with us a refracting prism, there would be twice as many waves striking the prism each second, which would make the relative wave-length only one-half. The result would be that the extreme red rays, at the line, A, would occupy nearly the position of the extreme violet rays, at the line, H. If we were to approach the sun at 200 miles per second, the lines would be shifted only $\frac{1}{1000}$ as much, but in the same direction. That is, the line, $D^1$, would nearly coincide with the line, $D^2$. If then we were to find a fixed star in whose spectrum the sodium lines appear, and if upon comparing the position of its spectrum we should find its $D^1$ line to correspond with the $D^2$ line of the sodium flame, we should know that we were approaching that star or it was approaching us at the rate of about 200 miles per second.

Here we reach the measurement of the invisible without making it visible; for there is no magnifying power which will enable us to see the motion of a star from or toward the earth. The only way it can become visible is by the enlargement of its disk when approaching us; and in the case of a star too distant to have a disk, of course this would be imperceptible.

This method has been applied to many stars, with varying results, indicating motions relatively to the earth, sometimes toward and sometimes away from us.

This method was recently applied to the star Algol, by Vogel. He measured the positions of the lines at different periods with reference to its minimum phase, and found that before the minimum Algol was receding from us, and that after the minimum Algol was approaching us. He repeated these observations often enough to make it certain that the change of its motion was connected with its apparent brightness. Although he could not see any companion, it was evident that there must have been a dark companion with similar and opposite motion, the two revolving about a common center. He deduced certain results with regard to the masses of the two stars thus connected with each other; but there seems to have been introduced as a link in the chain of reasoning more or less conjecture. I prefer, therefore, to pass on at once to another more remarkable discovery of the same character, which was made at about the same time by Professor Pickering at Harvard.

In photographs of Mizar, showing its spectrum, it was observed that some of the darker lines appeared double. At other times the same lines appeared single. By taking repeated photographs there was found to be a periodicity about this duplication of the lines, so that it could be predicted. What was the cause of it? Manifestly that the star Mizar, never seen optically as double in the most powerful telescopes, nevertheless is a binary star, the two components revolving around a common center of gravity in twice the period of the duplication of the lines. For calling the two stars A and B, when A is approaching and B receding, their lines will be separated by the difference of their relative motion; when A is nearest and B the most distant, neither will have any motion to or from the earth, and the lines will coalesce; then A recedes and B approaches, the lines again separating, but being transposed from their former position; and finally A will be most distant and B the nearest, when the lines will a second time have coalesced. Since the duplication occurred every 52 days, it is manifest that the period of revolution is 104 days.

It will be noticed that the distance of Mizar from the earth has no relation to this duplication of the lines;

it depends wholly upon the rate of motion of the two bodies, A and B, as compared with the wave lengths of the undulations of light. Were Mizar a million times, or millions of millions of times, as far away as it actually is, the separation of the lines would be the same; all the difference would be that being more distant the star would be more fainter, and being fainter its spectrum could not be so easily seen. Were our sun to be gradually removed from Mizar, the lines would grow fainter and fainter until they disappeared, but the amount of their separation would remain uniform. Nor does the distance of the stars A and B from each other at all affect the separation of the lines. Were they a million times as far apart, moving with the same velocity, the separation would remain the same; or were they a million times as near together, moving with the same velocity, the separation would remain the same.

The first thing ascertained from these observations was the period of revolution. Next we have the actual rate of motion. The relative motion causing the division of the lines is the sum of the motion of the two bodies. The two lines appeared equal in blackness, showing that the two stars are nearly equal in brightness; from which it may be inferred that they are nearly equal in mass. If so, the indicated motion of 100 miles per second is twice the actual motion of revolution. But as by the laws of motion it makes no difference in what proportion the mass is divided between the two bodies, it will be the most convenient to speak of one of the stars as stationary and the other in motion. We may now determine the size of the orbit; for if the motion is 100 miles per second in a circular orbit, and if it requires 104 days of such motion to complete the orbit, the circumference of the orbit must be about 900,000,000 miles and the distance of the two stars about 143,000,000 miles. This is but two million miles greater than the distance of the planet Mars from the sun, whose period is 687 days. As its actual motion is more than six times as rapid, revolving through the same distance in 104 days, the mass must be increased, to preserve a circular orbit, by the square of this ratio; showing that the mass of the two stars is about forty times the mass of our sun.

A few additional and new computations, based upon the most available assumption of brilliancy, may be interesting. Dividing this mass between two stars of equal density with our sun, and of equal brightness of disk, they would give about 15 times as much light. Adopting Sir John Herschel's estimate of the comparative brightness, that would correspond to a distance from us 9,000,000 times greater than that of the sun. This would correspond with a parallax of one forty-fifth of a second and a distance which would require nearly 150 years for light to travel. In miles, the distance would be 880 millions of millions of miles. The distance of the two stars optically would be one thirtieth of a second, far beyond the reach of Burnham with any telescope he will ever live to look through.

We have therefore the elements of the orbit thus determined, the distance apart of the two stars, the period and the masses. These elements are only approximate, however, for we have assumed the plane of the orbit to pass nearly through the earth. If the plane were at right angles with the line joining the star and the earth, there would be no relative motion of approach or recession, and no separation of the lines. Another star of equal brightness might be composed of two stars of the same size revolving in precisely the same manner, excepting that the plane of the orbit should be at right angles to us, and we could never by this method discover its duplicity.

Suppose that the orbit is between these two positions. Suppose that it is at an angle of sixty degrees with the line of sight. In that case the actual relative motion would be twice as great as the apparent relative motion. The actual distance of the two bodies from each other would be twice as great as our calculations would show; and the combined masses would be four times as great to preserve circular motion at this increased distance.

We have assumed circular motion. It would require a very considerable variation from a circular orbit to make itself apparent, or to materially affect our results. With an orbit as eccentric as some of the asteroids, the motion would be a little faster at a given distance with a given mass; so that a little less mass would be required than for a circular orbit. But the difference would be very much less than the uncertainty in the determination of the exact separation of the lines, and very much less than the uncertainty in the position of the orbit. Indeed it is manifest that if the plane of the orbit were very nearly at right angles with the line of sight, and yet the relative apparent motion sufficient to produce an appreciable separation of the lines, our computations by the above described method would be widely in error. On the other hand there might be a considerable deviation of the plane from coincidence with the line of sight, without materially affecting the computations; and the chances are strongly in favor of the supposition that the main element of uncertainty is the exact determination of the amount of the separation of the lines. If such discoveries should be many times repeated, including many fainter stars, it would then become probable that among them all there would be one or more to which our mode of computation would not accurately apply. The question would then arise for science to devise some new test to meet this emergency. And difficult as is the problem, we may reasonably expect success.

## THE REJUVENESCENCE OF CRYSTALS.

A LECTURE was recently delivered at the Royal Institution by Professor J. W. Judd, who introduced into his discourse several comparisons between the growth of crystals and animal and vegetable life, which rendered the curiosity-exciting title of "The Rejuvenescence of Crystals" extremely appropriate. The introduction of the microscope into the domain of crystallography, the lecturer said, has effected a wide extension of knowledge concerning crystal morphology and crystalogenesis. Since the days of Robert Boyle the investigations of numerous savants in Holland, Germany, and France, and of Brewster and Sorby in England, have opened up a new field of research to the scientist. The knowledge thus acquired has been of inestimable value to the geologist, who is compelled to appeal to the experiments and deductions of chemists and physicists for instances of analogy. But the debt is more than repaid by the new light thrown on questions concerning the formation of crystals by the investigation of natural crystallization by geologists. Nature is unstinting in the expenditure of time upon her handiwork, and her slow elaboration of crystals during millions of years accounts for the presentation by some natural products of curious phenomena that are not reproducible in test tubes and crucibles, although the causes of these phenomena may be determined by analysis. The first property of crystals to which Professor Judd drew attention was their possession of the power of resuming growth after an interval, no apparent limit of time existing after which resumption of growth cannot take place. Independently of the proofs of the truth of this axiom furnished from the laboratory, geology affords numerous examples of resumption of growth after an interim of millions of years, and also indicates that crystals formed by one process may continue their growth by another and completely different one. Thus quartz found in molten lava and crystallized from a fused mass surrounds itself with new matter and continues to grow when exposed to the action of silica in the state of solution, and an analogous instance is afforded by feldspar. To this alternate cessation and resumption of growth is due the formation of "zone" crystals, in which successive shells of different color and appearance have been incorporated, as may be frequently observed in the colorless shell surrounding a crystal of the amethyst variety of quartz.

The growth of crystals, as in the case of animals and plants, is powerfully influenced by prevailing circumstances, and in the mineral kingdom the principal factors to be considered are the temperature, the rate of deposition, the supply of materials and the presence of foreign bodies in juxtaposition. Recent investigations have shown that the presence of infinitesimal traces of some foreign bodies like water, fluorides, etc., may produce marked modifications of crystalline form, and although not entering into the composition of the crystals, appear to be necessary to that function. Hence they have received the appellation "mineralizers," and may be viewed as analogous to the diastase and ferments of the organic kingdoms. This action sometimes makes itself evident in the change of habit in the system, for instance, growing alum crystals pass from the octahedral to the cubic form if a trace of carbonate of potash be added to the solution, and it is remarkable that the crystals do not increase in measurement until the cubic form is assumed. The differences in color produced within the crystals by surrounding influences may be very marked or comparatively trivial, and the zones of color sharply defined or almost imperceptibly intermingled.

Changes in rate of growth may be indicated by the formation of irregular cavities within the crystal, filled with gas, liquid or vitreous substance, according to the origin of the crystals from volatile vapors, solution or a fused mass. These characteristics were beautifully illustrated by the lecturer, by means of specimens, diagrams and microscopic sections of crystals. A specimen of leucite was shown in which the original crystal had been corroded by the action of solvents, and the dissolved portion partially replaced by foreign amorphous matter during further growth. Another leucite crystal contained a ring deposit of hornblende, an augite crystal showed deposits of feldspar and magnetite, while the presence of oxide of titanium had been established in a specimen of mica.

In most cases Professor Judd pointed out that a succession of zones in a crystal is produced only by substances having analogous composition, as by the further growth of a chrome alum crystal in a potash or ammonium alum solution; but it is not necessary that the constituents of such a crystal be absolutely isomorphous, as is shown by the shells of red tourmaline frequently found surrounding green tourmaline. Further, the monoclinic augite sometimes forms compound crystals with the rhombic enstatite, cleavage cracks passing through both substances alike. It is evident that this intergrowth is not due to similarity of crystalline form, but to analogy in chemical composition, and similar instances may be cited of compound crystals of calcite and sodium nitrate, and of red zircon (a silicate of zirconium) with yellow xenotite (a phosphate of cerium and yttrium). At this stage of the lecture Professor Judd also exhibited various varieties of quartz, including a capped specimen, in which a zone of foreign material had formed a plate of weakness that rendered the detachment of a "cap" easy, and specimens of cotterite and red and amethyst quartz, in which the characteristic appearances are due to the occlusion of carbonate of iron and its subsequent partial or total conversion into oxide. The second property of crystals to which the lecturer made reference was the capability of repairing injuries during subsequent growth, and this part of the lecture was introduced by the experiments of Frankenheim of mutilating crystals and watching their further development under the microscope. The question how far by artificial mutilation particular forms can be given to crystals was next considered, but so much contradictory evidence exists that Professor Judd was able to make very few definite statements. In 1851 Lavelle showed that by cutting off one corner of an alum crystal and placing this mutilated side downward in an alum solution, the crystal resumes growth, but always retains a plane representing the artificial surface. On the other hand, in 1881 Loir showed that if injuries to a crystal be not too deep they will heal themselves before further growth of the crystal occurs, and by experimenting with alum crystals, he found that mutilated surfaces added new material more rapidly than the sound. As illustrations of such after-growth, Professor Judd exhibited microscopical sections of sand grains and of secondary outgrowths in hornblende. These considerations led to a comparison of the inorganic with the organic world. Only the rhizopods, corals, etc., of the animal kingdom are capable of reproducing themselves from portions cut off from their bodies, but in the vegetable kingdom instances of this nature are very numerous, while in the inorganic world the minutest fragments are capable of resuming growth after any interval of time has elapsed.

A third property of crystals referred to by the lecturer is that "two crystals of totally distinct substances may be so intergrown as to occupy the same space, or rather to occupy space between the same planes." A familiar example is the Fontainebleau sand, into the composition of which 40 per cent. of calcite enters without altering the crystalline structure. Professor Judd also exhibited a specimen of orthoclase intermingled with quartz, in which each constituent might be said to form the crystal, since both optically and in its principal features it was a perfect crystal of orthoclase on the one hand and of quartz on the other. Owing to this property or tendency to retain a certain crystalline form, a crystal may undergo profound internal changes, affecting optical and other properties, but so long as portions of the original remain, it is still capable of repairing injuries. These internal changes may be brought about by the solvent action of exterior agents, which leads to the permeation of the crystal by liquids and formation of cavities (negative crystals) filled with products of decomposition. This solvent action is well illustrated by the appearance of negative crystals, or ice flowers, in a block of ice when a beam of light is directed through it, and the Schiller structures in labradorite are also of analogous nature. The appearances of cloudiness and opalescence and the play of color and reflections at certain angles observed in some crystals are due to such internal alterations having taken place along certain planes by operations of this kind. All these three properties of crystals, Professor Judd said, are represented in the structure of granite, which was really the text of his lecture, although not delivered until its conclusion. In a section of tertiary granite from the Isle of Mull, Professor Judd pointed out the intimate incorporation of quartz and feldspar and the evidences of the struggle for dominion between these two constituents exhibited in the druses or internal cavities.

## ELECTRIC BLEACHING.

BLEACHING agents can be obtained from chlorides by electrolysis. Becquerel, in his *Electro-chimie*, showed that chlorine and sodium were the products of the decomposition of sodium chloride by the current from a 30-cell battery. Brand, in 1820, suggested that bleaching should be done by electrolysis of sea salt. Bouis showed, in 1862, that when chlorides are electrolyzed, hypochlorites are always formed if the temperature is not raised, and chlorates if the solution is used warm. Watt in 1851, and Hunter in 1857, also proposed to bleach by electricity, the former taking out a patent for his process. In 1862 Fitzgerald and Molloy obtained hypochlorites from chlorides by electrolysis, and further showed how the hypochlorites which had been exhausted in bleaching could be regenerated. In 1883, Naudin and Bidet took up the question, and while in the laboratory they were very successful, they failed when they came to apply their experiments on a large scale. M. Hermite began his experiments in 1888, and at first used sodium chloride; then he tried calcium chloride, and now finally he uses magnesium chloride, considering it to be the best salt. An electrolyzer is used made of galvanized cast iron, and from a pipe which runs along the bottom the solution of the electrolyte flows, while a channel near the top of the electrolyzer carries off the electrolyte to the bleaching tanks. The cathodes consist of a number of zinc disks mounted on a revolving spindle, and between each pair of zincs is the anode, formed of platinum gauze mounted in an ebonite frame. Generally a current of from 1,000 to 1,200 amperes at a pressure of five volts is used.

The anode ought to be a good conductor, cheap, and must not be attackable by the products of electrolysis; carbon, it would appear, seems the best for the purpose, and it has been employed; but Hermite finds that the carbons become disintegrated, and are therefore useless. Platinum is consequently the only substance which can be satisfactorily employed, but its use makes the electrolyzers very costly, and this fact has tended to prevent electric bleaching coming into use.

The interpretation of the various chemical reactions which take place during the electrolysis of the chlorides is difficult, though the formation of hypochlorites by the action of the chlorine liberated at the + pole upon the alkali liberated at the — pole seems a probable explanation. This does not, however, explain the great bleaching power of the solution, which bears no relation to the amount of chlorine it contains. This apparently abnormal property may be explained, though not proved, as follows. The water being decomposed at the same time as the water ozonized, oxygen is formed; this is soluble to a considerable extent in alkaline chlorides, and especially in magnesium chloride. Ozone has strong bleaching properties. Dutet observed that in the electrolysis of alkaline solutions the amount of oxygen evolved was less than it ought to be, and after investigating the properties of the liquid he came to the conclusion that alkaline peroxides having weak oxidizing properties were formed, but these being unstable have not been isolated. Now one of the conditions of the electrolysis of the alkaline chlorides is the alkalinity of the liquid, and in this we have a possible explanation of the phenomena in question. Another one is the probable formation of unknown oxides of chlorine, the chemistry of which is rather obscure.

But after all, the important question is—Will the electro-bleaching agents give results superior to chloride of lime? M. Hermite, in a pamphlet recently issued, states that an electrolyzer produces in 24 hours the equivalent of nearly 2 cwt. of dry chloride of lime (100 kilos.); this is stated to cost 20 to 22 francs (16s. to 17s. 6d.—in England this would only cost about 12s.) Where water power is available, M. Hermite places the cost at 5·22 francs (4s. 2d.), which shows a remarkable saving, only M. Hermite's statements are not proved by figures. Where steam is used, the cost is given as follows:

| | Frs. |
|---|---|
| Ten horse-power for 24 hours, consuming 240 kilos. of coal at 20 fr. the ton, | 4·80 |
| Thirty kilos. sea salt at 5 fr. 100 kilos. | 1·50 |
| Six kilos. magnesium chloride at 12 fr. the 100 kilos. | 0·72 |
| Interest and depreciation on dynamo and electrolyzer, | 3·00 |
| | 10·02 |

Ten fr. — 8s. In this estimate, taking 1 horse power hour as equal to 1 kilo. (22 lb.) coal at 20 fr. (16s.) the ton, an economy of 50 per cent. is effected. With less efficient steam plant and inferior coal the saving is less,

but still it shows a decrease in cost from the chloride of lime process. The use of the Hermite process is increasing, especially in paper works.

## BLEACHING BY PERMANGANATE OF POTASH.

POTASSIUM permanganate is a bleaching agent, whose powerful action has been, for years, known in practice. As far back as 1866, Tassié du Motay and others recommended this body as suitable for bleaching purposes, and, at the same time, mentioned the fact that the permanganate process was successfully employed in several factories. Pubetz, in 1870, confirming in the *Industrie Blaetter* the earlier statements, considers the use of permangante particularly adaptable to garment dyeing, and describes the bleaching method in detail. Quite recently, Seurati Manzoni (*Ind. Blaett.*, 1889) again called attention to permanganate of potash as a bleaching agent, and published extensive experiments for a practical method of applying it. I shall, says Mr. George Buchner, in the *Textile Colorist*, give a brief abstract of these researches, believing that, at the present moment, the potassium permanganate bleaching process has a claim to the interest of practicians, because the price of permanganate is, at present, much cheaper than at any time before. The price of the product has fallen 45 per cent. during the past ten years, and, at this cheap rate, mostly a very pure product is furnished, which contains about 95 per cent. permanganate of potash, while, formerly, often manganates of very low percentage, or permanganate of soda, were used for bleaching, which may have caused many failures. For this reason, also, new experiments in practice are recommendable. The two principal methods proposed of bleaching with permanganate are the oldest one, which was worked out about 20 years ago by Tassié du Motay, Pubetz, and others, and the new process of Manzoni. 1. After the older method, the tissues or yarns of cotton, linen, hemp, wool, etc., being cleaned with water, alkaline solutions, or soap baths, are laid down in a solution of potassium permanganate without, or with, an addition of sulphate of magnesia, until the bath is decolorized, that is, until the permanganate is decomposed, brown peroxide of manganese being precipitated upon the fiber, while a part of the oxygen of the permanganate affects the bleach. Chemically, this process is expressed as follows: $2KMnO_4 + 3H_2O = KHO + MnO_2H_2O + 3O$. By this action, free alkali is evolved which, in many cases, as in bleaching silk or wool, would act injuriously. To obviate this difficulty, the solution is, before entering the yarns, mixed with sulphate of magnesia, which prevents the formation of free alkali—innocuous hydrate of magnesia and sodium sulphate being formed. After the tissues have thus been exposed to the action of the permanganates, the oxides precipitated upon the fibers must be removed, for which purpose, the yarns are lifted from the bleaching liquor and washed in a dilute solution of sulphurous acid. Ordinarily, the yarns must, several times, be alternately treated in baths of permanganate and of sulphurous acid, and, finally, the bleached material is washed clean. As regards the quantity of permanganate employed in this process, Pubetz says: "A bleaching bath containing, according to the nature of the fiber to be decolorized, 4 to 10 lb. of permanganate of potash or of soda, is sufficient to bleach 200 lb. of cotton, linen, or hempen tissues or yarns." In the chapter on bleaching wool or woolen yarns, Pubetz further observes: "For 100 lb. well scoured wool, 4 lb. permanganate of potash or of soda must be mixed with 1¼ lb. sulphate of magnesia. Usually, a barrel of sufficient capacity is taken for this purpose, the solutions of permanganate and sulphate of magnesia poured in, and the material to be bleached loosely laid down in it." As regards the quantity of sulphurous acid required for the acid baths, the following is remarked: "The sulphurous bath is prepared in a special vessel. As much sulphurous acid is poured into the water as is required to destroy the manganese oxide fixed on the fiber." The wool, thus treated, is washed clean in water, and, finally, entered into a soap bath containing 1¼ lb. commercial soft soap, mixed with sulphite of soda, 48 lb. water, and ¾ lb. spirit of sal ammoniac, sp. gr. 0·9.

## TIN FROM TINPLATE SCRAP.

By Herr B. SCHULTZE.

THE solvent action of acid ferric salts upon metals is well known, but the property has not hitherto been utilized in the treatment of tinplate waste, for which purpose it answers perfectly. The solvent used may be either acid ferric sulphate, acid stannic sulphate, dilute sulphuric acid, or dilute hydrochloric acid, but in the two latter cases ferric hydrate, in the form of heavily rusted scrap iron, must be added. The tin, when dissolved, is precipitated by metallic iron, for which purpose, however, the solution must be perfectly neutral, and contain only protoxide salts, as the smallest excess of acid in the presence of persalts prevents the reaction. This condition is attained by passing the solution through a mixture of iron rust, metallic tin, and metallic iron, when the following reactions take place:

(1) $Fe_2O_3 3H_2O + SnOSO_3 + 3SO_3 H_2O = 2FeOSO_3 + SnO_2 2SO_3 6H_2O$.

(2) $SnO_2 2SO_3 + Sn = 2SnOSO_3$.

(3) $2SnOSO_3 + 2Fe = 2FeOSO_3 + 2Sn$.

The process, as practiced, includes three principal operations:

1. The solution of the tin.
2. The precipitation of the tin.
3. The treatment of the waste liquor.

When acid ferric sulphate is used, the tinplate cuttings are placed in iron baskets and lowered into the solution contained in an open wooden vat. The tin covering is completely stripped off the iron in a very few hours. The basket is then lifted out, the contents washed in water and picked over by hand, to separate portions still covered with tin, while the remainder, which is clean malleable iron, is pressed into balls for the heating furnace. The partially stripped portions are either returned to the dissolving bath or put aside to rust, in order to obtain material for the neutralizing vat. When the solution is saturated, as evidenced by its no longer acting upon fresh tinplate scrap, in which condition it contains mainly stannous and ferrous sulphates, probably a little stannic oxide and some free acid, it is passed to the neutralizing vat containing metallic tin and iron rust, where the excess of acid is neutralized, and the persalts are reduced as shown above. When an acid stannic solution is used, the method of proceeding is similar, the only difference being in the nature of the solvent. Instead of these solutions, dilute sulphuric or hydrochloric acid may be used in conjunction with ferric oxide or its hydrate, but with these the action is somewhat slower, from six to twenty-four hours being required to remove the tin completely.

The precipitation of the tin from the neutral stannous solution is effected by running it into vats containing clean metallic iron (scrap previously freed from tin). The reaction goes on slowly, the tin separating as gray metallic powder or in brilliant crystalline grains; but the reduction is complete, the exhausted solution showing not the slightest trace of tin. The precipitate, when washed and cleaned from iron by dilute sulphuric acid, is either melted or used for making tin salts. The green vitriol liquids from the precipitating vats are concentrated by allowing them to drop slowly over a large heap of cleaned iron scrap, which causes a rapid evaporation and a deposit of ferrous sulphate on the metal. This may be washed off and purified as commercial copperas by recrystallizing, or it may be used for forming the acid liquor for dissolving fresh quantities of tin. When the tinplate cuttings are varnished, the surface is cleaned by heating them with strong sulphuric acid at a temperature of 100°, which destroys the varnish in a very short time, leaving the tin surface exposed. When zinc is present, it should first be removed by treatment with dilute sulphuric acid as long as hydrogen is evolved. The plant and materials required are both simple and inexpensive. From 1 to 6 cwt. of chamber acid, worth from 1s. to 12s. are consumed per cwt. of tin obtained, worth £4 10s. to £5, in addition to 25 to 40 cwt. of iron, worth from £1 17s. to £4. The amount of coal required is inconsiderable. Both tin and iron are obtained in the highest state of purity.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